Iron and Steel Engineer

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J. F. KELLY, EDITOR

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Coming Meetings and Papers

ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS

CHICAGO DISTRICT SECTION

W. A. PERRY, Chairman — A. J. WHITCOMB, Secretary

WEDNESDAY, JANUARY 11, 1933

ELECTRIC ASSOCIATION ROOMS — 20 NORTH WACKER DRIVE, CHICAGO, ILL.

DINNER 6:30 P. M.

"SHOP PRACTICES AT THE INLAND STEEL COMPANY," by Victor E. Schlossberg, Asst. Supt., Electric & Power Departments, Inland Steel Co., East Chicago, Ind.

AN INTERESTING FEATURE OF THIS MEETING WILL BE A MOVING PICTURE OF THE NEW HOT STRIP AND COLD STRIP MILLS OF THE OTIS STEEL COMPANY, by John L. Young, Timken Roller Bearing Company, Pittsburgh, Pa.

PHILADELPHIA DISTRICT SECTION

C. M. THOMPSON, JR., Chairman — LINN O. MORROW, Secretary

SATURDAY, JANUARY 7, 1933

ENGINEERS CLUB — PHILADELPHIA, PA.

DINNER 6:00 P. M.

"HEAT DISTRIBUTION IN GAS, OIL AND ELECTRIC FURNACES," by J. W. Allison, Westinghouse Electric & Manufacturing Company, Philadelphia, Pa.

CLEVELAND DISTRICT SECTION

A. L. FOELL, Chairman — W. W. SPANAGEL, Secretary

FRIDAY, DECEMBER 16, 1932

ENGINEERS CLUB — CLEVELAND, OHIO

DINNER 6:30 P. M.

"THE STECKEL PROCESS," A. P. Steckel, President, Cold Metal Process Company, Youngstown, Ohio.

"ELECTRIC EQUIPMENT FOR STECKEL MILLS," by F. Mohler, Industrial Engineering Dept., General Electric Company, Schenectady, New York.

PITTSBURGH DISTRICT SECTION

J. W. BATES, Chairman — J. I. KASPARI, Secretary

SATURDAY, JANUARY 14, 1933

Afternoon and Evening, 2:30 P. M. and 7:00 P. M.

BLUE ROOM, WILLIAM PENN HOTEL — PITTSBURGH, PA.

"PRACTICAL METHODS FOR INDUCTIVE HEATING OF SOLIDS," by Dr. E. F. Northrup, Ajax Electrothermic Corp., Trenton, N. J.

"THE APPLICATION OF THYRATRON CONTROL TO RESISTANCE WELDING AND SOME OF THE RESULTS ACCOMPLISHED," by W. C. Hutchins, Industrial Engineering Department, General Electric Company, Schenectady, N. Y.

"PRECISION MEASUREMENTS OF MECHANICAL DIMENSIONS BY USE OF ELECTRICITY," by F. B. Terry, Asst. Manager, Gauge Division, Pratt & Whitney Co., Hartford, Conn.

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JANUARY MEETING ANNOUNCEMENTS WILL BE PRINTED LATER.

EDITORIAL

NEW USES FOR STEEL CAMPAIGN

BY

MECHANICAL, COMBUSTION, LUBRICATION, ELECTRICAL AND SAFETY ENGINEERING DIVISIONS

OF

ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS

You read in the November issue of the Iron and Steel Engineer that your Association would conduct a campaign on New Uses for Steel.

There is no question that the Association will render a valuable service to the Iron and Steel Industry, provided the membership will co-operate to its fullest extent.

The Steel Industry at the present time requires new markets, new outlets and new uses for its steel products and will welcome every assistance that our Association may extend to it in this connection.

You are therefore invited to participate in this campaign for New Uses for Steel and it is hoped that you will interest every employee of your plant, inviting him to make suggestions through you, on the following plan:

1st. The rules printed in the Iron and Steel Engineer will govern the contest.

2nd. All suggestions must come through the membership.

3rd. The prizes for the best suggestions will be paid to the membership only.

4th. It is suggested to every member in the Steel Plant that they conduct a contest for suggestions in their respective plant, or if that is not desirable, where there are a number of members in any respective plant that they pool their interests and conduct a joint contest for suggestions under one head. This will allow any employee of the Steel Industry to compete for a prize with his suggestions, the only stipulation being that any and all suggestions must come through the membership in that particular plant.

5th. The member or the joint committee of members may make their own rules as to the manner in which the money is to be distributed, that is if any one of the suggestions they offer are decided to be a winner of a prize.

6th. Here is an example: John Jones, of Plant A, conducts a contest for suggestions in his respective plant. He receives twenty-five suggestions from the employees of any department of that plant. Frank Smith, a non-member of the Association and one of the employees of that plant, makes a suggestion on a plain white sheet of paper, signs his name, his occupation, street number, city and state. This suggestion and any number Frank Smith desires to make is sent to the member or joint committee who in turn sign the name of the member conducting the contest and then forwards a copy of the suggestion to the Contest Editor. You are to keep the original suggestions in your file for a record of the suggestions going to the Contest Editor. If Frank Smith's suggestion wins a prize, the prize money will be sent to the member or joint committee who had charge of the contest at that plant who will in turn dispose of the prize money according to the rules under which they conducted their contest.

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Better Construction and Better Maintenance By The Use of Alloy Steels

By EARL C. SMITH
Chief Metallurgist, Republic Steel Corp., Youngstown, Ohio.

Presented before Cleveland District Section of the A. I. & S. E. E., November, 1932.

We, who live in this country, are undergoing a test which has been prolonged far beyond the desires of most of us. We are in the acute stages of an industrial depression, an economic depression that affects more than the industrial portions of our civilization. It probably is not as severe in an industrial nation, such as ours, as an agricultural nation of the type of China. Such upheavals have been recorded before, and it is probable that this one does not mark

EARL C. SMITH

the end of economic troubles. It is in such periods as these that the application of knowledge previously gained is utilized. It has been said that the ability of man to reason and think is the peculiar gift that differentiates him from animals. That man can think and reason is probably best understood when it is realized that very little thinking is done without pressure. Men can think but few do and usually only when under such stress as the nations of the world during the late war, or under the conditions of economic upsets which scrap industries and nations, wiping clear the traditions and developments and providing for an entirely new viewpoint. We, who are associated with the steel industry, are new in the economic world, since our industry is so recent that it cannot be said to be definitely established. We are therefore prone to wider swings than other economic groups. We move farther in our developments but tear down faster during our slow periods. We must search more often through the available materials of construction since we wear out or scrap more often than do many industries. We must search more often through these available materials of construction for another reason, we, the industry, are developing new materials at a rate that is difficult to measure. Even those extremely close to the new developments are constantly dismayed by the news of a major development which appears almost overnight to reorganize possibly a whole branch of the industry. No better example need be given than the application of electric power to steel mills. **The branches of the industry represented by The Association of Iron & Steel Electrical Engineers has been the cause of more profound changes than has any of the metallurgical processes.** It is therefore of peculiar interest to present to such a group some information concerning the tools available in the way of material which we, the steel industry, produce in our plants that may be of assistance in the eternal problem of better construction and better maintenance.

The early steel mills were rather crude affairs. They were very often associated with the iron working plants which had existed previously. These old iron working plants were generally small, serving but a local trade. When the steel making process, as we know, it came into existence the two were associated due to similarity. From about 1860 to 1890 it would be nearly fair to say that there was the iron business with some steel business. Of course, during the time from 1750 till within a few years there was the crucible melting method, but this never produced any quantity of material that could be considered in the terms of modern steel consumption. The iron business had history behind it, traditions associated with it. It took a depression period very similar to the present period to put enough pressure upon the world to evolve the steel industry. The reconstruction, following the serious economic disturbances which involved all nations of the world about fifty years ago, was with steel. Prior to that time civilization had builded with timber where temporary structures were desired, and stone where permanent edifices were intended. Iron, either cast or wrought, played but a minor part. The transportation both sea borne and on land depended upon wood. Iron was used in shipbuilding and this was replaced with steel. It is very interesting to read the discussions of the ironmasters of sixty years ago concerning these new products which were cast in ingot form ready to roll. It will be equally interesting a hundred years hence to read the discussions of the steelmakers of this age with reference to the materials we are producing and using for our construc-

tion. We should build well and reach as far into the future as caution will permit so that our structures may be among the last to go.

When one passes the work of a genius in an industrial way, we seldom appreciate it since industry is a recent thing in human affairs and we have not learned to measure its wonders.

When one crosses the Eads bridge at St. Louis there is nothing about the construction that advertises the fact that a very considerable amount of alloy steel was used. It is probably the first major construction job using alloy steel. A carbon steel with about one per cent chromium was very largely used and constituted a departure as radical as our modern steel airplane construction. Eads required more strength per unit of weight in his design than was available in the common materials of construction. He chose as the tool to accomplish his result the alloy chromium. He produced with this, a material that solved his problem. If the same viewpoint concerning alloys may be left with this group their usefulness may be better appreciated. Alloys are but tools to be used to do special jobs. Since the admirable application of Eads many other men of genuis have reached into the unknown and placed into the hands of the fabricators of metals other alloys and alloy steels which have wide usefulness. It has always seemed more desirable to refer to them as special steels since this designation has more nearly the implication that the combination used is a special tool for use in a peculiar circumstance.

If one looks at the pictures of the early industrial construction or at such relics as exist, no point about them strikes as forcibly as the massive parts. That they were exceptionally heavy were due to the materials from which they were made and the machinery used to make them. Precision in construction requires two things, precise materials and precise machines. The early builder was doubly handicapped. His construction material was wrought iron, cast iron and timber. The stress that could be used on the metal parts was very low. The cast iron members probably did not exceed 1000 pounds per square inch except in the highly stressed areas where the load might get up to 10,000 pounds if in compression. The wrought iron members were loaded to about 10,000 pounds per square inch. That we have made progress can best be measured by the comment that today a metal machine could stand such stresses at 1000°F. and would be safer from faulty workmanship. Not that this generation is more brilliant but we have moved a long way in the few years elapsed. We have moved so far that wrought iron is a curiosity and cast iron for serious construction almost as much as curiosity in spite of the fact that cast irons with about three times the strength of the old irons are regularly produced.

The earlier reference to chromium steel and its use to provide higher physical properties is typical of the applications. Chromium was known many years earlier. Even its ability to produce rust resisting alloys was known many years before any serious application was made for physical properties. In 1875 the steel makers of great Britain recorded as an important point that they had been told much about these chrome alloys. A specific mention was made that it had been proven that a steel containing two per cent chromium and less than one per cent carbon was actually ductile enough to permit bending cold. This alloy and the application of a nearly similar composition did little but call attention to the parent material, steel. The fact that steel was available and that it could be stressed to double the load of iron was the important discovery. Chromium went into the background and remained a minor metal until after the development of the automobile reappearing in a large way as chrome vanadium steel. Engineers heard so much of a material that was very new called Bessemer steel that they tried it out. This Bessemer steel was the middle ground into which the constructor first ventured. The fact that the chromium alloys were used and developed strength twice that of Bessemer steel made it possible for the constructor to point out that his step forward was quite safe. He did not attempt to use the unproven special steel. He pointed out that he wanted the best general material and could not afford to use the older materials since this offered no chance to improve his product. Such reasoning in the early '70s doubled the capacity of the American steel industry in about five years.

If we were to look back over the records of those days we would find that the boiler plants built for the new steel plants were of steel. Some of the very vital parts were still of wrought iron. The pressure used was about 100 pounds per square inch. This was a decided advance for the new material, steel was much more dependable than the wrought iron that had preceded it.

The rails to care for the enormous development of railroads of that time were made of steel. This was a startling advance and a terrible blow to the European producers of iron rails or the iron rails with steel heads. In the more radical of these railroad construction jobs the small cars were replaced with larger cars in which steel was an important part.

An early radical departure of bridge and car construction designed to handle heavier loads was the direct result of the construction of a railroad to haul ore to what was then known as Jones & Laughlin. The now Pittsburgh and Lake Erie might be considered the earliest of the modern railroads. It might still serve as an admirable example of excellent use of high grade materials.

Following the great depression of the '70s and '80s the next serious spot in our history was in the late '90s. In this period in which the political history was so similar to today we again saw our industries drop back to the despair point and hang at low production figures so long that the country became more upset than it is today. As one studies the history of our industry in those days many references to the Duquesne revolution turn up. Now this revolution was really the construction of the big blast furnaces. Furnaces that made as much per day as did the usual furnace in a week. Many reasons have been advanced for this revolution. The important ones were the discovery of new ore bodies of enormous size and the confidence of engineers in their new materials to construct these enormous units. By this time open hearth steels were crowding the Bessemer products to perfection. The new material as in the past offered something for the genius to use in a peculiar way and pave the road for the ordinary engineer who wanted to take the

last ounce out of the conventional materials. The net result was the development of steel for construction purposes. The spread from the plants to the country practically removed the wooden railroad car. It permanently removed timber from the heavy construction field. It eliminated the wooden boat from the seas. It even altered the armament of the military and naval units of the world. It was an important factor foreshadowing the great European world war, and proved in its final conclusion to be the decisive point. Steel was so cheap and so dependable that engineers used it freely in every line.

The development of our naval affairs during this period offered to the genius the outlet for his energies. Most of the groundwork was laid in the desperate race of the European nations to keep up to each other and largely the developments were European. The most important of these was the nickel armor plate. This was a French invention that replaced the bolted composite plates of steel and iron. It was first presented to this country in the early '90s in the historic Annapolis test. It made obsolete the navies of the world and caused every thinking engineer of that time to consider it with relation to his peculiar problems. By the time the depression at the turn of the century was over nickel steels were established and alloy steels were no longer curiosities. They were regular production in all the important munitions plants in Europe and America. Before the great volume of naval construction had ceased the enormous field of automotive industry had opened and these steels became very common. Curiously these steels have been used very largely outside our industry. "Every one's children have shoes but the cobbler's."

Where design required great weight as in the railroad locomotive field only the reciprocating parts and the axles were made from these new materials. In our industry this limitation did not hold so narrow a field. A great deal of equipment existed in which compactness was of interest. Special gears which could withstand great wear and carry heavy loads were an early development. These gears were made from bar stock forgings and often castings. Compared to the soft steel gears which had displaced cast iron gears, the new materials offered increase of strength about four times the normal. This increased strength could be used to strengthen an existing machine or permit the redesign of an existing unit. It became fairly common to replace a troublesome gear with an alloy gear of the same dimensions. Troublesome table gears were regularly replaced with chrome or chrome vanadium gears, and later with chrome nickel and nickel gears. The desirable quality of the nickel steels with or without chromium is to treat from very low temperatures which permits good hardness, little strain and very little distortion. Any part that is machined before treatment and used in the nearly full hard state should be considered as properly a nickel steel requirement. This is especially true if the part requires case carburizing before use in which instance the surfaces will be very hard. Where very large units are being made that require treatment, nickel steel will be found very desirable. The problem of strain is very important in such designs. Very heavy parts such as big shafting, big gears should be nickel or nickel chrome. The extremely deeply quenched parts are better of chrome nickel molybdenum in which the nickel and manganese are fairly high. The outstanding feature of the nickel series is toughness with hardness and the only reason for lessened use is cost.

Where hardness is the more important problem the alloy usually selected is chromium. It is a deep hardening alloy. In amounts between one and one and one half per cent its hardness varies from low carbon soft materials to the ball race materials of extreme hardness where the carbon is about one per cent. Chromium is the one alloy that covers the entire range of usable hardness. It is the most widely used although not the simplest to use. Up to twenty points of carbon and carrying not over one per cent chrome it is the most desirable carbonizing steel that is available for the price. It suffers from the fact that it quenches so hard that distortion is a real problem. It is very common in parts which can be ground before assembly. Above the carbonizing range it is the one steel that must always be considered. Preference should be given on account of cost any time it is possible to use it. In one inch round it is water quenching to thirty five points of carbon with one per cent chrome and is machineable and usable to about 150,000 pounds per square inch tensile. This indicates that safe design stress can be nearly 70,000 pounds. By increase of carbon as the size increases this figure can be carried through the range of small shafting say three inches, and need only be dropped to 60,000 design stress in the sizes over four inches. It is nearly the economic answer to all parts which are machined after treatment and used without further retreating. Where the hardness must be excessive and machine work done the addition of molybdenum permits work of difficult character to nearly 200,000 pounds. At the present time one piece of work is regularly bored, threaded, drilled at 387 to 418 Brinell with a yield point of 165,000 pounds per sq. inch and ultimate of nearly 200,000. It has one competitor in this field in the very expensive nickel chrome material with about three and one-half per cent nickel and one per cent chrome. The nickel chrome material is machineable at 200,000 ultimate strength but is difficult to work and quite expensive.

When one considers the distance traveled from 10,000 pounds per sq. inch design stress to 100,000 pounds design stress and still retain machineable material the progress in making the material and the more startling job of making the cutting material are better appreciated. The increased strength can only be used when the part can be shaped for use. Above 200,000 pounds per square inch machining is no longer practical, and grinding is used. Calculations have been made that indicate the theoretical strength of ferrous material as a possible million pounds per sq. inch. It is of interest to note that there are anti-friction bearing assemblies now in use that are carrying unit pressure loads of half that amount indicating that the stress is of the order that might be considered the fatigue limit for ferrous materials. This means that the modern anti-friction bearing is carrying unit loads fifty times that possible a little over one hundred years ago. If the present depression did nothing else than increase the use of anti-friction bearings and develop lubricants for these terrific pressures we might witness a revolution equaling that which developed with the railroad for land trans-

portation The steel industry has at the present time the revolutionary wide strip sheet mills to evaluate. These are purely the application of higher unit stress at the working points and involve anti-friction bearings to cope with the handling of these higher stresses. One is prone to be impressed with the big things. A wide strip mill, with its hardened chrome molybdenum steel working rolls backed up by hardened steel rolls usually of the same general chemistry, is impressive. The massive anti-friction bearings on the roll necks of the backup rolls carry very heavy loads. One mill has bearing capacity of 100,000 pounds per inch of working roll face. One cannot help but be impressed and often loses sight of the important fact that the little parts of any machine may take advantage of the same engineering that the big machine has by virtue of its value made possible. Shear blades, crane wheels, wear plates, shafting, dies, rolls, stressed bolts, in fact every part that wears out or breaks in service can be considered. It is surprising the multitude of places that a skillful applier of alloy steels can find in a steel mill to use his tools.

To the apparently complicated problem of physical structure of alloy steels which have strength as their main item there has been added the construction from steels which do not corrode as rapidly. Corrosion is a peculiar problem and divides itself into types of corrosion. We are all familiar with the corrosion of a metal such as iron in an acid like sulphuric. This is a form of wet corrosion and is quite common. We are less familar with the corrosion caused by scaling of metals for it has been usual to replace scaling metals with refractories of a non-metallic character. This dry corrosion has until lately been a limiting factor in the use of metals at high temperatures. A third and quite uncommon type of corrosion is gas corrosion as for instance sulphur gases at high temperatures. This was so destructive that until very recently metals were considered as unfit for such service. This depression period is the proving ground for the new member of the steel family, the chromium alloys usually referred to as stainless and heat resisting materials. These steels have physical qualities that are very desirable. They have in fact better physical qualities in general than do the usual alloy steels. Properly treated they combine marvelous strength and exceptional corrosion resisting qualities. They have in certain compositions the peculiar ability to stand stress at high temperatures. It is no longer essential to consider metals as unsatisfactory for furnace interiors. Heat resisting steels are regularly used at temperatures of 2000° F. and extremely important assemblies are working even higher. These metals deserve careful consideration for they have many applications still waiting for the genius to uncover. No spectacular job like the Eads bridge has been advertised to attract attention to them and steel mill men still consider them as foreign to their industry. To those more intimately associated with their manufacture their application is less a problem. They have been tried in many places. The usual method is to work a piece of scrap into shape for a trial application study this and move gradually to the major applications proving the ground as one proceeds.

The most widely used of these steels is the chromium nickel material, about .10 carbon, carrying 18 per cent chromium and 8 per cent nickel. It was originally a German development and did not have much production in this country till about six years ago. It is a non-magnetic ductile material, but little harder than soft steel but which will harden upon cold working to more than double its strength in the soft state. It is very resistant to all ordinary forms of corrosion except sulphates. It is nearly immune to ordinary atmospheric corrosion, and is widely used. In the mill it will handle all the ordinary problems of rust corrosion. It can be electric or gas welded and the welds are ductile and corrosion resistant. It is difficult to machine, but can be worked satisfactorily. Modifications of analysis are available for intricate machine work. It is satisfactory as a heat resisting material up to about 1300° F. but should not be considered a true heat resisting steel.

Where corrosion is not acute and where welding is not a factor in assembly the more economical plain chrome with from 12 to 18 per cent chromium is very useful. It is soft, easily worked, and will be satisfactory in service in most cases where the corrosion is only of the wet type. Like the 18 chromium 8 nickel material it is not resistant to sulphate corrosion.

Where the problem of heat resisting material is encountered the simpler types do not perform well. The simplest addition to develop heat resistance is the addition of silicon. The scale formed is very tenacious and the effect of oxidation is minimized by the fact that the first scale strips off only under exceptional circumstances. It is reasonable to feel that if the original scale hangs on the surface below it erodes very slowly due to the protecting action. Heat resisting steels are therefore essentially non-scaling steels.

Heat resisting steels offer another tool for construction in that they are not only non-scaling, but also very strong at high temperatures. They can hardly be classed as steel since they are really heat resisting alloys in which both the carbon and the iron of steel are only incidental. The simplest is the high chromium steel carrying about 25 to 30 per cent chromium. It is very resistant to sulphur gases and is used where this is the major problem. It is not very ductile cold, but quite ductile when hot. It therefore does not work well in units that require frequent dismantling.

When enough nickel is added to these high chromium steels, say over 25 chromium to make them ductile, when cold, a very satisfactory material is possible. The series with 25 chromium 12 nickel and about one per cent silicon fabricates well and will be ductile when cold. It is not satisfactory in high sulphur gases. It is the general low price heat resisting steel. It makes admirable material for all construction that does not exceed 1800° F.

Where exceptional service is planned that would mean temperatures over 1800° F. the usual material contains 25 chrome, 20 nickel and 2 silicon. It is made in a steel mill but that might be said to be the only reason for calling it a steel. It is an interesting material. Practically scale free, up to 2000° F. and about as strong at 1500° F. as wrought iron when cold. It is really a metallic refractory more like the Nichrome series. It is quite resistant to sulphur gas corrosion and is generally satisfactory for all manner

of furnace construction. Many thousands of dollars are invested in cast alloys of about this type in normalizing furnaces which operate at about 1800° F. Above 2000° F. heat resisting alloys are required.

The heat resisting materials are forcing a new viewpoint into the welding of metals. Other materials worked at lower temperatures could be joined by other methods. The heat resisting steels are only satisfactorily assembled by welding and have presented many problems. These steels as a class are much more sensitive to procedure than the simpler steels. They have as a class a peculiar characteristic of absorbing a lot of certain gases just above their melting point only to give it off if heated very hot as metals are when arc welded. If the proper procedure is used the welds are sound. The study of welding of the simpler materials will eventually explain this. The expense involved in construction of large units from these materials by welding make it imperative that more be known of these metals.

The general subject of metals and temperature could be the topic for a week's meeting. In fact the volume covering the A.S.T.M. discussion has more than 700 pages of information. This volume now in permanent form with the discussions might be considered a sort of handbook in the field. To those interested in critical study of this field this volume will be found as a most useful foundation.

Such a meeting as this will have served its purpose if but one person be interested enough to apply but a single idea to practical use. It seems that it is but appropriate to ask the consideration of such a group as this for more interest in the welding of metals by the metallic and carbon arc methods. It is peculiar of electric welding that it is known only to electrical men and used only by mechanical men. It is realized that such a statement is an exaggeration but in principle it is correct. The associated workers in our industry do not know and with a well founded dread of electricity will be some years getting even a working knowledge. If the electrical men and mechanical men who use electric welding would observe their metals closely they would discover that much variation existed. So much so that it might and probably will be a method of test before many more years. It is peculiar that neither the makers of steel nor the metallurgists of steel mills have understood welding to a degree that would be useful. It is customary to get steel any place as long as it is fairly low carbon and weld or not and charge the whole affair to the welder. If the co-operative observation of the welders and mechanics in the steel mills can be focused on steels that weld and steels that require skillful handling before they can be welded it will be possible to produce at all times good welding materials. With our present knowledge of the art no maker of steels wishes to consider a specification for welding steels. Such a group as this can furnish to the industry the vital information in the way of specimens of good and bad material. If it is attracted to the attention of the welders that better material will certainly be available as soon as it has been determined why it is better, these men will soon locate and deliver to their metallurgical co-workers enough samples to furnish the test material. It might serve to bring closer contact between the welders and the steel makers. Under present conditions the welder is a man whom the steel maker sees only as a friend who helps out in time of breakdown. Neither may realize that they are both steel makers. To venture a prophecy is rash, but when the welders look to the accumulated experience of the melter for characteristics of liquid steel the melters will look to the welder for new information concerning the product from their furnaces. The history of this depression will be very closely bound up with the success of these two groups in knowing each others requirements. New steels will, in fact are, being made. New construction will be possible, as witness the German cruisers. If one spectacular job of world wide fame could come from welded steel, alloy or otherwise, we might see an entire reversal of the present trend. Such is not impossible when one considers that experimental alloy steel construction has been accomplished where the weight strength ratio is equal, in fact slightly exceeds that possible with the aluminum alloys. It is of more than passing interest that it depends upon electric spot welding. So to the electrical engineers of our industry we ask consideration. Show the way to a new era.

It will be interesting to note a report on all steels used for various parts with their hardness and reason for using.

No.	Type of Steel	Parts Used For	Brinell Hardness	Reason for Using
1	SAE 1015 Common steel .10 to .20 Carbon .30 to .60 Mang.	Collars, stopper pins & rods, hooks, bolts, braces, bars, ravels, scrapers, etc.	None	Ordinary forgings (gen'l work)
2	SAE 1045 Common steel .40 to .50 Carbon .50 to .80 Mang.	Wrenches, crane hooks, wedges, turnbuckles, foundation bolts, couplings, collars, studs and screws, etc.	None	General forgings that require a little more toughness.
3	SAE 2320	Carbonized parts.		General carbonizing steel.
4	SAE 2340 Nickel steel .35 to .45 Carbon 3% to 3.5% Nick. .50 to .80 Mang.	Special bolts, pins and studs, special shafting.	302-321	Highly stressed bolts to stand friction, etc.
		Gears.	418-477	
5	SAE 3140	All shafting under 5" rd.	269-302	Heat treated to best physicals to stand all kinds of service.
6	SAE 3150 Chr. Ni. steel .35 to .55 Car. .50 to .80 Mang. .45 to .75 Chr. 1.00 to 1.50 Ni.	Holders for jaws on stretcher levelers, ingot rams, pump shafts, rods, etc.	250-300 269-302	Must be very stiff and not brittle.
7	SAE 3195	Cold metal cutting such as slitter blades.	578-600	Cutting edge.
8	SAE 4145 Chr. Moly. steel .40 to .50 Carbon .40 to .70 Mang. .80 to 1.10 Chr. .15 to .25 Moly.	Shafting under 5" rd. Press dies.	269-302 302-350	Has good machining qualities at fairly high hardness. Must resist wear but must be machined after hardening.
		Special cold cuts.	555-578	Requires a very critical treatment to develop toughness at high hardness.
9	SAE 5140	Pinions and gears.	444-512	Must resist wear of hardened cast gears.
10	SAE 5150 Car. Chr. steel .35 to .55 Carbon .50 to .80 Mang. .80 to 1.10 Chr.	Shear blades for all bar mills for hot cutting.	418-512	Must resist wear at fairly high temperatures.
		Sheave wheels, sprockets and large pins, etc.	302-350	Very tough at this hardness.
11	SAE 6140	Pinions and gears of all kinds.	444-512	Must resist wear.

No.	Type of Steel	Parts Used For	Brinell Hardness	Reason for Using
12	SAE 6150 Chr. Van. steel .35 to .55 Carbon .50 to .80 Mang. .80 to 1.10 Chr. .15 to .20 Van.	Pins and studs for rollers and pig machines.	495-555	Must resist wear of chilled iron. No lubrication.
		Hot cutting shear blades for all bar mill shears.	418-512	Must resist wear at high temperature, not as good as Chr. Ni.
		Track wheels for cranes.	477-512	Moly. 50-55 Carb.
		Rolls and shafts for large Hyatt bearings.	444-512	Must resist wear against Hyatt bearings.
		Pins for Harrington stokers.	477-555	Must resist wear against hardened rollers. No lubrication.
13	SAE 9250 Si. Mang. steel	Chipping chisels.	600-627	Must hold cutting edge under bad condition.
	.50 to .55 Carbon .60 to .90 Mang. 1.80 to 2.10 Sil.	Special hand chisels. Punches and dies for punch presses.	495-532 495-555	Must be especially heat treated.
14	Chr. Ni. Moly. .30 to .40 Carbon	Knife liners for mill shears.	302-321	Must resist wear of hardened shear knife.
	.50 to .80 Mang. .60 to .80 Chr.	Piston rods for hammers and press.	302-321	Must resist shock (machine after hardening).
	.25 to .35 Moly. 1.50 to 2.00 Ni.	Some small shafting.	255-300	Used only when SAE 3140 is not available.
15	Chr. Ni. Moly. .50 to .60 Carbon .50 to .80 Mang. .60 to .80 Chr. .15 to .25 Moly. 1.50 to 2.00 Ni.	Die blocks for hammers and press.	321-495	Must not wear under high temperature.
		All crane track wheels.	444-512	Must be hard to resist wear, must not slip on rail.
		Large rolls.	418-495	Never much success with large rolls.
16	Chr. Ni. Moly.	Casing for Hyatt bearings (large).	350-418	Must have material that will harden in large section.
17	2¾% Ni. steel .25 to .35 Carbon .70 to .90 Mang. 2½ to 3.00 Ni.	For all large parts too big to quench and draw.	240-269	Very good for high impacts after toughening treatment of normalize and draw.
18	Nickel Moly. .10 to .20 Carbon .30 to .60 Mang. 1.50 to 2.00 Ni. .80 to .30 Moly.	Lifting blocks for engine valves, set screws, special bolts, pins.	Carburized and hardened to 627-652	Very good case hardening steel for parts that must have very hard surface.
19	Car. Van. steel .80 to .90 Carbon .15 max. Van. .40 max. Mang.	All cold cutting shear knives.	512-555	Must have good cutting edge.
		Jaws for straightening.	600-627	Must be hard and have strength.
		Rollers for roller leveler.	555-600	Must resist wear.
		Pistons and nozzles for air hammers.	600-627	Must be very hard and tough.
20	Crucia steel .80 to .90 Carbon .30 to .50 Mang. .20 to .35 Chr.	Hammers for hammer mill.	600-627	Must resist continual wear.
		Cracker shear knives.	600-627	Must have good cutting edge.
		Draw bench jaws.	555-600	Must have str'gth and hardness.
		Forming rolls.	600-627	Must be very hard.
		Stems and nuts for punch press.	512-555	Special ht. treatment required.
		Jaws, pipe cutters, rolls, tools, hand chisels, bars, dies, etc.	600-627 512-627	Special heat treatments.
21	Car. Van. High Manganese (.70-.80) .40 to .50 Carbon .15 to .20 Van.	Hot mill screws. Locomotive axles. Very large shafting. Large rams. Charging machine peels. Arbors for Enduro grinders. All large tough forgings.	(Normalize and draw)	This steel has very high str'gth when treated in this manner, and is not hard to machine with a good fine grain.
22	High Carbon High Chrome .95 to 1.10 Car. .20 to .50 Mang. 1.20 to 1.50 Chr.	Rollers for Harrington stoker.	600-652	Must be very hard to resist wear.
		Ball races for all cranes.	600-652	Must be very hard to resist wear but not brittle.
		Rolls for straightening machine.	600-627	Needs special treatment.
		Roller leveler rolls.	555-600	Needs special treatment.
		Lathe centers.	600-652	Needs special treatment.
		Tong bits, etc.	None	Hold up on edge at high temperature.
23	Toncan Ena. Stk. .02 to .04 Carbon .10 to .15 Mang. .001 to .005 Sil.	Side sheets for locomotives.	None	Resist corrosion better than steel plates.
		All working parts in galvanizing machine vats.	None	Slow solution in zinc.
24	KA-2 & KA-2-S Enduro 18-8 .04 to .12 Carbon .40 to .50 Mang. .20 to .30 Sil. 17.00 to 18.00 Chr. 8.00 to 9.00 Ni.	Skid bars for sheet and pair furnace.	None	Stands up under heat.
		Soot blowers and nozzles.	None	Stands up under heat.
		All bolts and tie rods for acid cars.	None	Stands up under acid.
		All metal parts on car type furnaces.	Annealed	Stands up under heat.
		Some pump shafts, valve seats and rods.	Annld.	High in resisting vibration loads.
		Or		
25	22.00 to 25.00 Chr. 17.00 to 20.00 Ni. .15 Carbon .40 to .60 Mang. .1.00 to 1.50 Sil. KNC-S-Enduro	All places where heat is a factor.	Annld.	Will not rust.
		Some valve seats.	Annld.	Does not cut out at high temperature under heavy pressure.
		Best type made by us for resisting heat.		
26	Nitralloy G-H .20 to .40 Carbon .40 to .60 Mang. .20 to .30 Sil.	Shear Cams.	Annld.	Must resist wear under pressure.
		Roller leveler rolls.	Annld.	Must resist wear under pressure.
		Valve seats and bonnets.	Annld.	Must resist wear under pressure.
	1.20 to 1.30 Alu. 1.50 to 1.60 Chr.	Bushings and shafts on straightening machines.	Annld.	
	.15 to .25 Moly.	Nozzles in O.H. Burners.	Regu'r Treatments	Will not cut out.
		Pins on Harrington stokers.		Not in service at this date.
27	Type "V" steel High Chr. Sil. .60 to .70 Carbon .30 to .40 Mang. 2.00 to 3.00 Chr. 3.00 to 4.00 Sil.	Rollers for reels at 8" mill.	627-652	Must resist excessive wear at high temperature.
		Tong bits (not available at all times).		
28	Straight Carbon Spring steel .90 to 1.05 Car. .25 to .50 Sil.	Coil springs of all kinds.	402-444	Must resist shock.
		All tongs for corporation.	302-418	Special treatm'ts.
		Furnace tools, bars, etc.		Special treatm'ts.
29	Chrome Tungsten .80 to .90 Carbon .30 to .40 Mang. 1.90 to 2.10 Chr. .75 to .90 Tung.	Chipping chisels.	578-600	Must be very hard and tough.
		Special tools.		Special treatm'ts.
30	Engine Bolt Stk. .10 to .15 Carbon .30 to .50 Mang. .20 to .30 Sil. .50 to .70 Ni. .10 to .20 Moly.	Side guard bolts, many other special bolts. Stay bolts.	None	Used when sudden jar without twisting operation is applied. Has given very good service.
31	Wrought Iron .02 to .05 Carbon .50 to .70 Mang. .15 max. Sul. .15 max. Phos.	All chains over entire corporation.	(Annealed at interv'ls)	Must have extra stretching qualities.
		Some special bolts and studs.		Absolutely no brittleness (safety item). Must be flexible.
32	Ni. Moly. Cast. .35 to .45 Carbon .50 to 1.00 Ni. .20 to .30 Moly. .60 to .80 Mang. .20 to .40 Sil.	Large gears, bevel gears, gas producer fingers and all large castings, where hardness and toughness is a factor.	380-495	Getting very good results without much breakage or other brittleness.

Synchronous Ties

By H. A. WINNE
Industrial Engineering Department, General Electric Co., Schenectady, N. Y.

Presented before the Chicago District Section of the A. I. & S. E. E., April, 1932.

A discussion of the different electrical methods of obtaining synchronous, or approximately synchronous, and in many cases also adjustable, speed relations between two or more motor drives.

The title of this paper may cause considerable wonder in the minds of those who have not had occasion to make use of some of the various forms of "synchronous ties." Let me state at the outset that it does not involve that much discussed (between husband and wife) subject of neckties, nor railroad ties, either of wood or arc welded steel. A synchronous tie, in the sense in which the words are used in this paper, is a method of insuring synchronous, or

H. A. WINNE

approximately synchronous, speed relations between two or more motor driven mechanisms. In many applications this synchronous relation must be maintained under varying conditions of load and speed, and it must also be possible to adjust the ratio between the speeds of the various motors. In other words, an adjustable synchronous tie is often needed.

In this paper I shall not attempt to discuss fully the question as to when and where synchronous ties should be used, but shall limit myself to a consideration of the various methods of obtaining synchronous, or approximately synchronous, ties, and a brief description of some of the applications which have been made. My remarks will be confined, in general, to the developments by the General Electric Company, with which I am most familiar.

1. Simple Synchronous Motors

Obviously, the simplest form of synchronous tie is the use of synchronous motors for the driving units. This method has recently been used on a six-stand continuous bar mill, where three synchronous motors each drive two stands, replacing the usual single motor with lay shaft and bevel gears. With this arrangement the speed ratios between the various drives can not be changed unless some mechanical system, such as cone pulleys and belt, is introduced between the motor and the driven device. Neither can the speed of all the drives be changed simultaneously unless they are supplied with power from an adjustable frequency source.

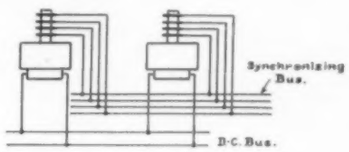

FIG. 1—D-c. motors synchronized by connecting collector rings to common bus.

2. D.C. Motors with Collector Rings

A method which was used about 1909 for synchronizing the speeds of d-c. motors driving sections of a paper machine was to equip each d-c. motor armature with 2-phase collector rings. Corresponding rings on the various motors were then connected to common buses. If one of the motors tended to slow down, its armature would drop back slightly in angular position, which would cause a-c. power to be delivered to it from the remaining motors, holding it in step. Under this condition the other motors would be acting partly as d-c. motors delivering mechanical power, and partly as inverted rotary converters delivering a-c. power to the motor which was trying to slow down.

This system possessed two disadvantages. The amount of power which could be transferred thru the collector rings without seriously affecting commutation was small, as a converter requires a much weaker commutating field than does a straight motor. Adjustment of speed ratios necessitated cone pulleys, or other arrangements which transmitted the full power of the drive. This latter was really the most serious handicap.

3. D.C. Motors with Auxiliary Belted Synchronous Motors

A number of sectional paper mill drives were built, beginning about 1919, in which the synchronous tie was obtained by belting a small synchronous motor, thru cone pulleys, to each main d-c. motor, and electrically connecting these synchronous motors to a common bus. The strength of the tie was, of course, limited to the pullout torque of the auxiliary synchronous motors, but for the service involved it was found perfectly satisfactory to use synchronous motors of about 20% of the capacity of the main motors. With this arrangement the cone pulleys and belts permit of adjusting the speed ratios of the various drives, and are called on to transmit only a small amount of power.

4. D.C. Motors with Revolving Frame Auxiliary Synchronous Motors

A further step in the development of synchronous ties for paper mill service eliminated the power transmitting cone pulleys. An auxiliary synchronous motor was geared or direct connected to each main motor, and all synchronous motors were connected to a common bus. Then in order to provide for some adjustment of speed ratio the frame of each synchronous motor was made rotatable, and driven by a small adjustable speed d-c. motor. Obviously, by varying the relative speeds of the frames of the synchronous motors, the relative speeds of their rotors, and consequently of the d-c. motors, could be changed in the opposite way.

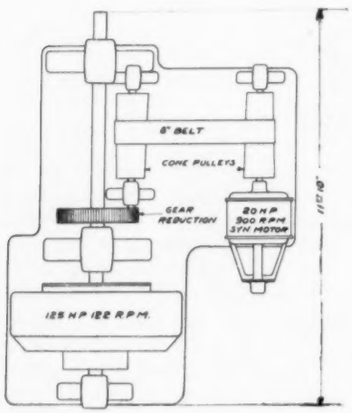

FIG. 2—D-c. motor with belted synchronous motor for speed synchronizing purposes. All synchronous motors connected to common bus.

Inasmuch as most of the early development work on synchronous ties was in connection with paper mill sectional drives, we may as well follow the development of apparatus for this application thru to the present time. All of the foregoing methods of tying together d-c. motor speeds depend for their success on the actual transmission of power from one device to another, so that the d-c. motor which is tending to run too slowly may be relieved of some of its load. Of course, a drooping speed-load characteristic for the d-c. motors is presupposed. The last two schemes were both quite successful, but involved rather expensive auxiliary apparatus. Consequently, regulators were developed which operated directly on the field circuits of the main d-c. motors, and still gave a synchronous tie.

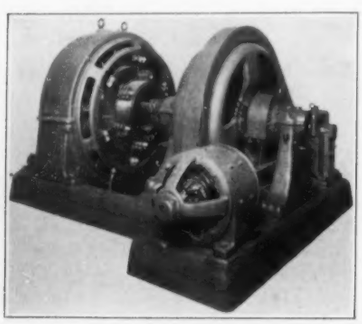

FIG. 3—D-c. motor with direct connected synchronous motor. The synchronous motor has a rotatable frame, driven by the small d-c. motor.

5. Dynamometer Type Regulator

One of the most successful types of paper mill regulators is the dynamometer type. A fractional horsepower synchronous motor is mounted so that its frame is free to rotate thru part of a revolution, and is mechanically connected to the brushes on a stationary commutator whose segments connect to taps on the resistor in the main motor field circuit. Movement of the synchronous motor stator thereby changes the resistance in the motor field circuit. The rotor of the small synchronous motor is driven by the main motor thru a small set of cone pulleys. The stator is electrically connected to a bus, in common with the other regulating equipments in the mill, which is fed from a three phase generator driven by an adjustable speed d-c. motor.

Now, if we apply a given a-c. frequency to the stator of the synchronous motor, and drive its rotor at exactly synchronous speed, the frame will not move. If the main d-c. motor, and therefore the rotor, tends to slow down, and therefore drops back slightly, a torque will be exerted on the frame, causing it to rotate and thereby adjust the commutator type rheostat. Thus, each d-c. motor is held in constant speed relation to the a-c. bus frequency, and therefore to all the other motors.

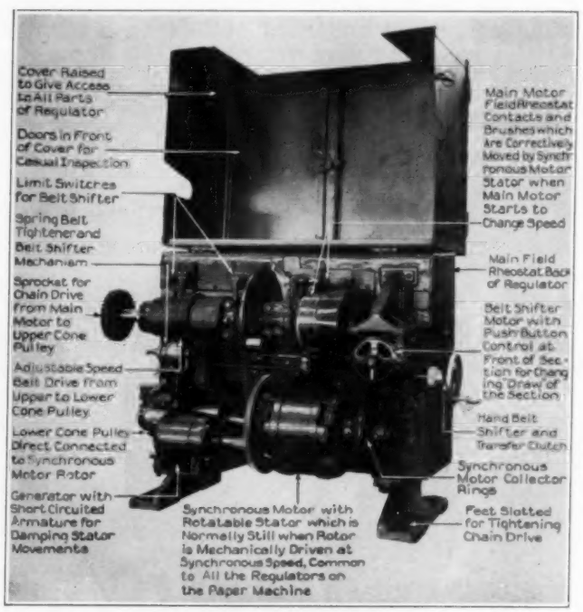
Cover Raised to Give Access to All Parts of Regulator
Doors in Front of Cover for Casual Inspection
Limit Switches for Belt Shifter
Spring Belt Tightener and Belt Shifter Mechanism
Sprocket for Chain Drive from Main Motor to Upper Cone Pulley
Adjustable Speed Belt Drive from Upper to Lower Cone Pulley
Lower Cone Pulley Direct Connected to Synchronous Motor Rotor
Generator with Short Circuited Armature for Damping Stator Movements
Synchronous Motor with Rotatable Stator which is Normally Still when Rotor is Mechanically Driven at Synchronous Speed, Common to All the Regulators on the Paper Machine
Feet Slotted for Tightening Chain Drive
Synchronous Motor Collector Rings
Hand Belt Shifter and Transfer Clutch
Front of Section for Changing Draw of the Section
Belt Shifter Motor with Push Button Control at
Main Field Rheostat Back of Regulator
Main Motor Field Rheostat Contacts and Brushes which are Correctively Moved by Synchronous Motor Stator when Main Motor Starts to Change Speed

FIG. 4—Dynamometer type regulator, with commutator type rheostat controlling speed of d-c. motor.

6. Selsyn-Carbon Pile Type Regulator

A still more recent regulator development is shown in Fig. 5. The principle of operation of the Selsyn transmitters, receivers, and differentials are quite well known, but will be explained more in detail later in this paper. The regulator proper consists of a carbon pile rheostat, and a Selsyn differential so arranged that rotation of its rotor changes the pressure on the rheostat.

A master Selsyn transmitter, d-c. motor driven, feeds the stator of the Selsyn differential. Another Selsyn transmitter, driven thru cone pulleys by the main motor, feeds the rotor of the differential. So long as the two Selsyn transmitters rotate in synchronism there is no motion of the differential. If the main

motor tends to slow down or speed up, the corresponding change in the relative angular position of the two transmitters will cause enough rotation of the differential to make the required adjustment in the carbon pile rheostat. An ingenious mechanical connection between the differential and the rheostat permits adjusting the leverage so that the amount of change in resistance for a given movement of the differential can be varied to compensate for different operating conditions.

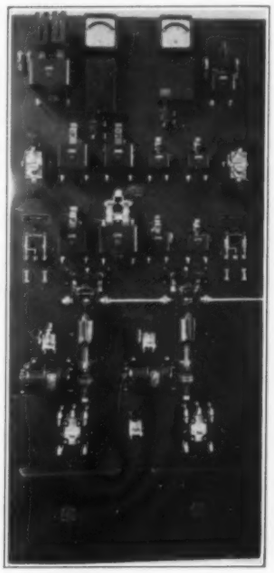

FIG. 5—Regulators of the Selsyn-carbon pile type mounted on a control panel. Carbon pile resistors are in rear.

Both the dynamometer and the carbon pile type of regulator are particularly suitable for applications where the conditions of load and speed are fairly steady, and not subject to rapid and violent fluctuations. They have not been used on steel mill main roll drives, but the dynamometer type has been successfully employed to control the speed of a rotary flying shear.

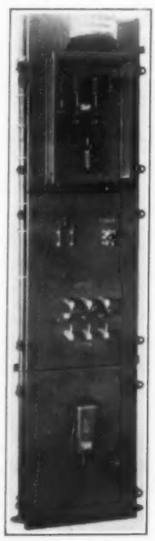

FIG. 6—Balanced voltage vibrating type speed regulator.

VIBRATING TYPE REGULATORS

7. Voltage Regulator with A.C. Pilot Generator

One of the earliest applications of speed regulators to steel mill main roll drives was in connection with the 14" continuous hot strip mill installed in 1922 in what was then the Trumbull Steel Company's plant at Warren, Ohio. The finishing stands of this mill were individually driven by d-c. motors, and the mill builder felt that synchronous ties were necessary on these drives.

A single phase a-c. pilot generator was geared to each mill motor. The armature circuit of this generator was carried thru the coil of a "Tirrell" voltage regulator to a motor operated dial switch connecting to taps on the primary of a small transformer. The secondary of this transformer was loaded by a bank of condensers or capacitors. The contacts of the regulator operated in the field circuit of the main motor. Therefore, the regulator held constant current in its coil by adjusting the field of the motor. This, of course, maintained constant speed. Changing taps on the auto-transformer necessitated a change in voltage of the pilot generator in order to maintain the regulator balanced, and therefore the motor speed was adjusted in this way.

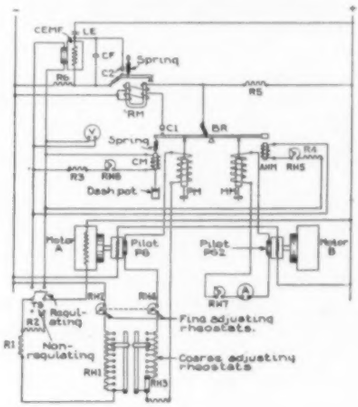

FIG. 7—Elementary connections for balanced voltage vibrating type speed regulator.

8. Balanced Voltage Regulator

A type of regulator which has been used in a considerable number of continuous mill main roll drives is illustrated in Fig. 6, and an elementary diagram of connections is shown in Fig. 7. This is essentially a voltage regulator of the Tirrell type in which the pull of one coil on its plunger is balanced against that of a similar coil instead of a spring.

As shown on the diagram, a small direct current pilot generator is geared or coupled to each main motor. These pilots operate with their field structures highly saturated, and excited from a constant voltage source, so that the armature voltage is proportional to the speed. One main coil, PM, of the regulator is connected to the armature of the pilot generator through rheostats RH4 and RH3. If only two machines are to be synchronized, the other main coil MM of the regulator is connected to the pilot generator on the second motor as shown. If several motors are to be synchronized, the master coils MM of all the regulators are connected in series through a rheostat to a constant voltage source.

Contacts C1 of the regulator control secondary relay RM, whose contacts in turn operate across the field of the small counter-emf. generator, the armature of which is in series with the shunt field of the main motor. When contacts C1 and C2 close, the field of CEMF is shunted, thereby decreasing the voltage of CEMF, and increasing the field current on the main motor. Similarly, when the contacts are open, the field current of the main motor decreases.

Now if the speed of motor A tends to increase, the voltage of pilot generator P-G, and consequently the lifting force of coil PM on its plunger, will also be raised. Consequently, contacts C1 and C2 will close, the voltage of CEMF will drop, and the motor field current will rise, restoring it to the proper speed.

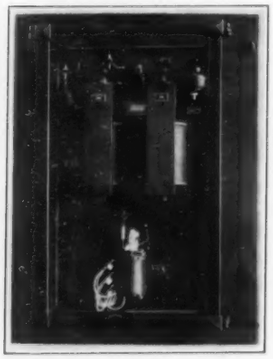

FIG. 8—Dynamometer type of balanced voltage regulator for speed control.

AHM is an anti-hunting magnet so connected that when the regulator contacts open it immediately pulls them closed. The result is that the regulator vibrates continuously with the contacts remaining closed just a sufficient proportion of the time to keep the motor excitation and speed at the correct value. CM is a magnet which compensates for the pull of AHM and prevents it from unbalancing the regulator.

To change the speed of motor A with respect to the other motors, it is only necessary to adjust rheostats RH3 or RH4. These vary the resistance in the regulator coil circuit, thus requiring the motor and pilot generator to run at a higher or lower speed in order to maintain constant current in coil PM.

It will be noted that mechanically connected to RH3 and RH4 are rheostats RH1 and RH2, these latter being in the motor field circuit. The resistance of these is so proportioned with respect to RH3 and RH4 that at all times the field circuit is adjusted to give approximately the motor speed called for by the regulator, and thus the regulator has to provide only a small range in field current.

The regulator can easily be taken out of service whenever desired by throwing switch TS, and the speed controlled by manipulation of the same rheostat control switches as are used when operating regulating. As far as the pulpit operator is concerned, he controls the adjustment of motor speed by exactly the same motions, whether operating regulating or non-regulating.

9. Dynamometer Type Balanced Voltage Regulator

A modification of the balanced voltage regulator is shown in Fig. 8. This works on essentially the same principles as the regulator just described, but with this difference. The element at each end of the balanced lever consists of a moving coil and a stationary exciting coil. A larger magnetic circuit is employed, and the regulator is capable of exerting greater torque and is more sensitive. The pilot generator is connected to the moving coil, while the stationary coil is excited from a constant voltage source.

A large number of balanced voltage type regulators are installed on main roll drives, and have operated very successfully. This, or in fact any vibrating type, regulator has the advantage of low inertia moving parts, and it can almost instantly insert or remove a comparatively large counter-emf. in the field circuit and momentarily "force" the field in order to get quick response. It is a very satisfactory regulator for use when load changes are sudden and violent.

Of course, in applying any regulator to a d-c. motor field, it must be remembered that it takes time to change the amount of flux. Therefore, when a load is suddenly applied the motor will quickly slow down a small amount, because counter-emf. of the armature must decrease in order to let the increased current flow. While the regulator immediately gets busy to decrease the flux and bring the speed back to normal, a finite amount of time is required to do this. Therefore, when load is very suddenly applied a momentary drop in speed will occur, regardless of the type of regulator used, and even if the motor has a rising speed-load characteristic.

Therefore, no regulator working in the field of a d-c. motor can give a true synchronous tie, if the load fluctuations are violent, but the results obtained answer all practical purposes.

SELSYN CONTROL SYSTEMS

A Selsyn instrument is very like a miniature bipolar rotating field alternator. The rotor has a single phase shuttle winding, while the stator has a distributed three phase Y-connected winding. Electrically the Selsyn device acts as a transformer, with the rotor excited from a single phase source. The magnitude of the voltages induced in the three elements of the stator winding depends on the angular position of the rotor.

The simplest Selsyn system consists of two instruments with rotors excited from a common source, and with the terminals of one stator connected to those of the other. If both rotors are free to turn, they will take up a position such that the stator voltages are of balanced magnitude and displacement. If one rotor is turned with respect to the other, the voltages of the two instruments will be unbalanced, causing a current to circulate through the stator windings. This will provide a torque tending to turn the rotors to a position such that the stator voltages are again balanced, or until they are in "correspondence."

Thus, if one instrument, the "transmitter", is rotated, the rotor of the "receiver" tends to follow its motion exactly. The amount of torque available is roughly proportional to the sine of the angle between the two rotors.

A Selsyn differential is similar to a simple Selsyn instrument except that its rotor has a distributed three phase winding. A simple differential Selsyn system consists of two standard units and a differen-

tial. The stator of one unit is connected to the stator of the differential, and the stator of the other unit to the rotor of the differential. The rotors of the two standard units are excited from a common source.

For one position of all three units the impressed and induced voltages in the rotor of the differential will be equal, and no current will flow. Any deviation from this position will cause current to flow and torque will be exerted tending to restore correspondence. If one rotor is held, and another is rotated, the third rotor will follow the rotation of the second. Any one unit will always indicate the angle between the other two.

10. Selsyn Operated Rheostat

Selsyn units have been used in various ways to provide synchronous ties. As previously mentioned they constitute an important part of the latest paper mill regulator. In cement manufacture it is desirable that the rate at which "slurry" is fed to the kiln should be porportional to rate or rotation of the kiln. The kiln is driven by an adjustable speed d-c. motor, and the feeding wheel by another smaller motor. A Selsyn transmitter is coupled or geared to each of these motors so that when the two motors are running with correct speed ratio the speeds of the Selsyn units are equal. A Selsyn differential, electrically connected to the two transmitters, is mechanically coupled to the field rheostat of the feeder motor. So long as the two transmitters are in synchronism, the differential stands still. If the speed of the kiln motor is adjusted by hand, thus unbalancing the system, the differential will rotate at a speed corresponding to the difference in speeds of the two transmitters, adjusting the rheostat in the feeder motor field until the balance is restored.

Obviously this scheme is suitable only when load changes and speed adjustments are infrequent and gradual, and where departure from synchronism for short times will not cause difficulty. The speed ratio could be made adjustable by interposing cone pulleys or a similar arrangement between one motor and its Selsyn transmitter.

11. Selsyns and Photo-Tubes

A combination of Selsyns and photo-tubes is being used to synchronize a hook conveyor with a pin

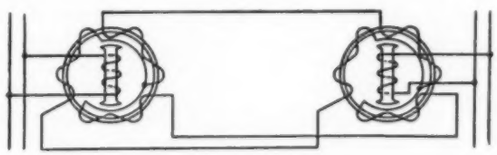

FIG. 9—Schematic diagram of two standard Selsyn instruments.

conveyor on a rod mill. The pins on the latter conveyor are spaced 10 feet apart, as are the hooks on the first conveyor. It is necessary that a hook arrive at the point of transfer simultaneously with the pins, in order that the coil may be successfully transferred. Furthermore, it must be possible to run the pin conveyor backwards, with the hooks stopped and then when both are started forward they must automatically resynchronize.

Each conveyor is driven by an adjustable speed d-c. motor. To each motor a Selsyn transmitter is geared so that it makes exactly one revolution while the conveyor is traveling 10 feet. The stators of these two units are connected to a Selsyn differential on the shaft of which a slotted disk is mounted. Photo-electric cells are placed at one side of this disk and a light source on the other. When the speeds of the two motors are in the correct ratio, the disk is stationary. If the pin conveyor tries to run a little too fast, the disk starts to rotate in one direction, bringing a slot in line with a photo-electric cell, which in turn, thru relays, energizes an auxiliary field on the pin motor and slows it down. If the pin motor runs too slowly the disk moves in the oppo-

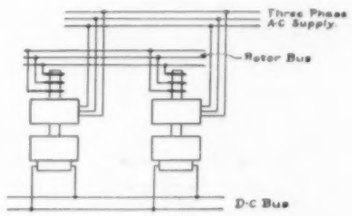

FIG. 10—Schematic diagram of d-c. motors with power Selsyn units for synchronizing speeds.

site direction, another tube is illuminated, and the auxiliary field is excited in the opposite direction, speeding up the motor.

There is a second Selsyn differential connected in series in the system. This is mounted in a case out in the mill and connected by worm gear to a hand crank. If, due to stretch or slippage in the drive, the conveyors tend to drift out of synchronism, the operator can readily bring them back by turning this crank.

There are, of course, a number of possible variations of the Selsyn control method of obtaining a synchronous tie. In the combination of two standard instruments and one Selsyn differential, the differential may operate a field rheostat, or it may be equipped with contacts which in turn control a field rheostat, or contactors in a d-c. armature or induction motor stator or rotor circuit.

There are also various ways in which two standard Selsyn instruments may be used in combination with relays or Thyratron tubes. For example, suppose a Selsyn instrument is driven by each of the motors which are to be controlled. Then if the stators are electrically connected together, and a single phase voltage is applied to one Selsyn rotor, the induced voltage in the other rotor will be exactly in phase with the applied single phase voltage only when the two rotors remain in fixed angular relation, or in other words in synchronism. Any deviation from exact phase coincidence can be made to operate a relay or tube which in turn causes the variation to be corrected.

Power Selsyns

When the Selsyn instrument is made large enough so that it can transmit sufficient power to hold the main drives in synchronism without the use of any auxiliary control devices, it is termed a "power Selsyn." In the majority of installations of this type a standard 3 phase wound rotor induction motor acts as the Selsyn device.

One of the most recent and spectacularly successful applications of the power Selsyn is the General

Electric unit drive equipment for rotary newspaper presses. The various units of the press must run in synchronism, else the paper will break. To mechanically connect the various units would require a large quantity of shafting, gears, clutches, and bearings, which are eliminated in the unit type drive with Selsyn tie-in.

So each unit is driven by an individual direct current motor, of perhaps 35 hp.—1250 rpm. Direct connected to each motor is a 3 phase, 40 hp., 8 pole wound rotor induction motor. Corresponding rings on the rotors of all these motors, or power Selsyns, are connected together, but no connection is made between rotor phases. Their stators are all connected to a 3 phase, 60 cycle power supply, with phase rotation such that when the drive is in operation the Selsyn rotors run against phase rotation.

To understand the operation of the power Selsyn equipment it is simplest to consider conditions in two units at standstill. Full induced rotor voltage, at line frequency, exists between the rings on each unit. So long as each rotor is in exactly the same angular position with respect to its stator, it is obvious that the voltages across the rings of the two units will be of the same magnitude and phase angle, and no current will flow between them.

Now suppose we displace one rotor slightly. The voltages of the two will be at different phase angles, and current will flow between the two rotors. This will cause current to flow between the two stators, and we have circulating currents flowing between the two machines. The interaction between the rotor currents and the flux in each machine will be such that torques will be exerted in each motor tending to bring them back to a position of correspondence. The current flow, and torque, will increase as the angle of displacement increases, but it is simply a circulating current between the two units, and no power is drawn from the a-c. supply, except to furnish the magnetizing current for the stators. Maximum synchronizing torque, equivalent to at least 80% of the pull-out torque of the unit when operated as a straight induction motor, will be obtained at approximately 90 electrical degrees displacement. On an eight pole motor this is equivalent to 22.5 mechanical degrees.

When the drives are rotating against the phase rotation of the stator excitation, the conditions are the same as at standstill, except that the rotor voltage and frequency vary. If the drives should rotate in the same direction as the phase rotation it is apparent that at synchronous speed there would be zero voltage and frequency across the rings, and therefore no synchronizing torque could be exerted. However, as the speed departs from synchronism, the available synchronizing action increases fairly rapidly, so that so long as we select Selsyns with a proper number of poles we can be sure of sufficient synchronizing torque, even for reversing service.

For example, suppose we wish to maintain synchronous operation of two 600 rpm. direct current reversing motors, and we have 60 cycle power available. Then, to make sure we will always have at least half line frequency, or 30 cycles, between rings of the Selsyn power units we must select machines whose synchronous speed is at least twice the d-c. motor speed. In other words, a 6 pole—1200 rpm. induction motor would make a satisfactory power Selsyn for this drive. When running at 600 rpm. against phase rotation the ring frequency would be 90 cycles; at zero rpm. it would be 60 cycles; and at 600 rpm. with rotation it would be 30 cycles. The rotor voltage would, of course be proportional to the frequency. Thus at any operating speed there would be sufficient voltage available so that any variation from synchronism would cause current to flow, exerting synchronizing torque.

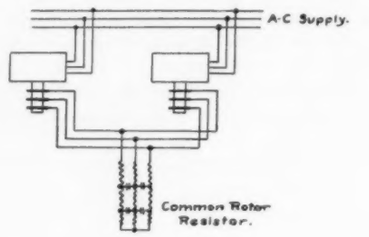

FIG. 11—Wound rotor induction motors with common rotor resistor for synchronizing speeds.

A recent application of power Selsyns is in connection with a lift bridge. The lifting mechanism at each end of the bridge is operated by a wound rotor induction motor. To each driving motor is coupled a duplicate motor which acts as a power Selsyn to synchronize the two drives, thus insuring that at all times the bridge will remain level. In the past it has been necessary to mount a single drive in the middle of the bridge, with a system of cables to keep the bridge level. With the power Selsyns it has been found possible to lift the bridge by applying power to only one driving motor, the other end being driven through the Selsyn.

Obviously this type of synchronous tie could be applied to side guards, edging roll adjusting drives, etc.

Wound Rotor Induction Motors with Common Resistor

A method which can be used to obtain a limited amount of synchronizing torque between two induction motors is to connect their rotor rings in parallel to a common starting resistor, and leave some resistance in the rotor circuit at all times. Now, so long as there is load on the motors, and therefore current flowing through the rotor circuit, there will be voltage between rings proportional to the load and to the amount of resistance in the rotor circuit. Any variation of the two rotors from a synchronous relation will result in an angular difference between the two rotor voltages, causing rotor and stator currents to flow and exert torques tending to maintain synchronism. Obviously this scheme has a rather limited field of application.

None of the power Selsyn schemes described permit of any adjustment of the relative speeds of the drives, unless some mechanical means such as cone pulleys or hydraulic gears are used to couple the Selsyn to the drive, or the drive to the driven mechanism.

The foregoing discussion by no means covers all available methods, but from it I think you will agree that there are a good many ways of electrically coupling two or more drives together, either rigidly or adjustably. Which scheme should be employed for any given drive can be determined only by a thorough study of all the conditions surrounding the application, and with a full knowledge of the characteristics of motor drives and "synchronous ties."

The Influence of Modern Electric Equipment Design on Brush Performance

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President, Electro Service, Inc.,
Union City, N. J.

Presented before Philadelphia District Section
of the A. I. & S. E. E.

GENERAL. The general impression among users of modern electrical equipment is that brushes wherever applied for contact making purposes have not improved as the service demands or as some may view it, they have not kept step with the advances of the equipment in general. We may well take this fact for granted without doing severe injustice to the carbon brush, as will be shown by three main points which contribute to this condition.

W. SIEBENMORGEN

THE DESIGNER in building his equipment has the assistance of many industries. Sheet iron, used in magnetic circuits, has decreased losses and high permeability. Steel castings for magnetic paths of constant density are being replaced by rolled steel sections with uniform and more favorable magnetic properties. Insulation materials are improved giving higher protection for spaces available. Copper is uniform and of high conductivity. Materials such as steel and bronze may be stressed more, allowing speed of equipment to be increased, thereby giving an almost proportional increase in yield per pound of effective material. Forced ventilation carries off the heat generated, thereby reducing temperatures. The combined result of these facts is much smaller apparatus for the same output.

APPARATUS, thus created is uniformly reliable though the safety factor over the old equipment is perhaps not as high. Modern industry now takes this apparatus and uses it in a highly specialized field, where the rate of production is carefully pressed to its maximum safe limit. The relative demand is far greater on equipment than it was in the past. It does happen that a piece of apparatus is designed for 50% overload for one hour following a run of full load. It duly meets the specifications on the test floor. Now, however, after it goes into service, it may be forced to meet these conditions in an entirely different way than was originally intended. The % of overload does not exceed the specifications, neither does the time condition but the equipment has to meet this service day in and day out and not occasionally. It becomes in practice a machine of intermittent duty of larger capacity though its load factor may be low.

THE LITTLE CARBON BRUSH is now fitted into this picture. Some perhaps 42 years ago we stumbled on the idea that carbon would do well for a contact making device (See E. Thompson in the Electrical Engineer, Vol. 18, p. 335, 10/3/94.) At that early time the brush was just carbon to the chemist, perhaps somewhat coarse, impure, poorly bound but carbon nevertheless. In all these years, it has changed little. It is still carbon to the chemist after a laborious method to finish it. Not that refinements have been absent but no major changes were possible. The same piece of carbon which ran the little 5 H.P., 110 volt, 600 RPM motor in the 90's operates today on a reversible planer motor that makes perhaps 25 complete cycles per minute. The very usefulness of the little brush in the beginning held back improvements for years. One could not apply such features as ventilation, speed increase, chemical changes, density, etc. It is no small wonder, therefore, that it appears to have stayed behind the times.

EQUIPMENT. It is not the purpose of this article to show the development and design of a modern machine using carbons but in order to understand brush performance and effect, it is imperative that some of the fundamental principles be thoroughly understood as they apply to reactance voltage, armature reaction, commutating poles, compensating field, armature equalization, double brushes, brush rigging and brush holders.

REACTANCE VOLTAGE. The function of the brushes on the commutator of a continuous current machine is to carry current to and from armature coils while these coils pass under brush and reverse their normal current from one direction through zero to the opposite direction. Fig. 1. Brushes **Commutate** the current. Since the armature coil has self induction the reversal of current generates a voltage called **Reactance Voltage.** It is approximately proportional to the square of the number of turns per coil, directly proportional to length of armature iron, speed and current, it is lowest for wide, shallow, open armature slots. The reactance voltage has the same direction as the decreasing current in coils at the beginning of reversal since it opposes this reversal, it also is opposite to the increasing current in coil toward end of reversal. It is therefore in the same direction during whole period of commuta-

tion and its resultant **Short Circuit Current** (B. Fig. 1) added to the imaginary and ideal main current A1 gives the actual current A2 in coil undergoing commutation. At the instant C when commutator bar connected to this coil leaves the brush, the current A-2 has not reached the proper value, it **arcs** over from brush to segment. Machine **sparks.** The circuit in which the short circuit current flows consists of the coil of practically neglible resistance and the contact face of brush in both **positive and negative** direction (Fig. 2). If now the contact resistance between brush and commutator, **contact drop,** is high the short circuit current will be reduced and commutation improved.

ARMATURE REACTION. A further complication is introduced by the magnetic influence of the armature current as a whole on the field flux. Symmetrical magnetic field due to field winding alone, armature not carrying current, is shown in Fig. 3. Fig. 4 shows magnetic field set up by armature current when field current is zero. It is perpendicular to above main field. DE is the position of brushes for **no load neutral.** With both main field current and full load armature current supplied simultaneously the combination would be a motor rotating clockwise as in Fig. 5. The field is distorted now as a result of **armature reaction. A voltage curve along commutator** will now show that density is very high under **entering pole tip. See Fig. 6.** The brushes if left in position DE Fig. 5 would cause a voltage in the wrong direction to be generated in coil undergoing commutation, and sparking would increase. To correct this, brushes have to be moved to a **full load neutral** position. D-1, E-1 is now the position that corresponds to DE at no load but proper full load position of brushes is still further back at D-2, E-2 where the fringe of field flux from pole-tip generates a current in coil approximately equal but opposite in direction to the short circuit current B in Fig. 1. This new current may be represented by F, Fig. 1. The machine now runs sparkless at full load, since F added to A-2 gives A-3 which has reached the normal strength at time when segment leaves the brush, see Fig. 1.

We can now make some simple deductions.

To get sparkless commutation at full load of a motor (Non-interpole) brushes must be moved against rotation from no load neutral. For a generator, brushes should be moved with rotation.

The shifting of brushes has the result of slightly weakening the main field, causing slight increase in speed of motor and decrease in voltage of generator (Fig. 5, Current in coils D-2 to D-3 is demagnetizing).

The high field density under entering pole tip of motor (Leaving Pole tip of Generator) may increase the **average voltage between commutator bars** to a dangerous point. Fig. 6 shows this plainly. This feature is one cause of **flashing** in motors, and explains why generators do not flash quite as readily, the high voltage point being further away from leaving edge of brush.

For any load, other than full load a corresponding brush position **must** be found if sparkless operation is desired. Fig. 7 (by Prof. Morecraft, Columbia University), shows how current under brush at light loads may increase and cause sparking if brushes are left in full load position.

The effect of armature reaction may be reduced by modifying the design of pole pieces as is shown in Fig. 8. The "Lundell" pole and the "unequal air gap" pole have unequal distribution of field at no load, which is made approximately normal by the influence of armature current. Design applies to non-reversible machines only. "Saturated pole tips" and "slotted poles" simply introduce a magnetic reluctance in path of armature reaction thus reducing its effect.

COMMUTATING POLES. To overcome the necessity of shifting brushes for variable load the commutating pole was introduced some 30 years ago (Pfattischer of Electro Dynamic Company and others). Today practically all machines are provided with **commutating poles** or **interpoles.** These are small poles midway between main poles provided with a winding which is in series with the armature. Fig. 9. To understand their function it is necessary to remember that approximately 85% of the total strength of interpole winding is equivalent in size but opposite in polarity to the armature fields strength. This creates a neutral zone on armature at point where brushes are located. In this zone the remaining 15% of interpole excitation generate in the coil undergoing commutation a voltage equal and opposite to the reactance voltage, neutralizing thereby the short circuit current and obviating the necessity of moving brushes into a pole fringe to generate this voltage. Fig. 10 gives an exaggerated idea of the approximate field forms (voltage along commutator) of interpole machines under various conditions for both motor and generator operation. Fig. 11 shows typical "brush drop" curves taken in conventional manner on a modern 3500 KW 250 volt rotary. Curve D gave black commutation in this case. It may be stated here however, that on most machines the best operation is obtained when this curve lies somewhere between B & D (machine slightly overcompensated).

Commutating poles function automatically being in series with armature. They generate a voltage in coil undergoing commutation more or less proportional to amount of armature current, they reverse with armature current, they are not affected materially by main field strength. Their effect may be adjusted within limits by varying their air gap and inserting non-magnetic material between interpole core and the machine frame or their windings may be shunted. This shunt should be inductive if load is subject to rapid variation to get the time constant of shunt the same as that of main winding. From these fundamental principles we come to the following further conclusions:—

Motors with speed variation by field control and generators with field variation for Ward-Leonard control would be nigh impossible without commutating poles.

Brush position is essentially constant for an interpole machine.

If necessity for change of brush position arises the change will be found to be comparatively small.

A reversed interpole causes vicious burning at brushes and changes in speed etc. because the whole winding (15% effective plus 85% compensating) creates a strong field around interpole zone interfering with main field.

By providing special windings interpoles may be

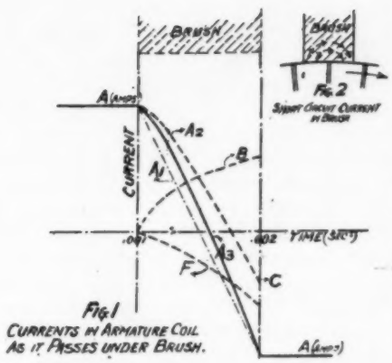


Fig. 1
CURRENTS IN ARMATURE COIL AS IT PASSES UNDER BRUSH.

Fig. 2
SHORT CIRCUIT CURRENT IN BRUSH

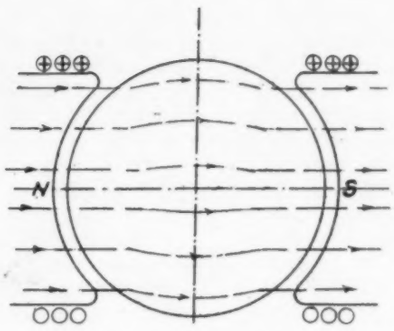


Fig. 3 — MAGNETIC FIELD PRODUCED BY FIELD WINDING ALONE

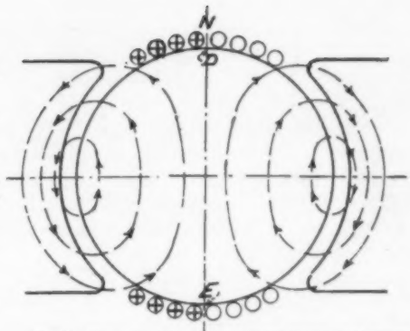


Fig. 4 — MAGNETIC FIELD PRODUCED BY ARMATURE CURRENT

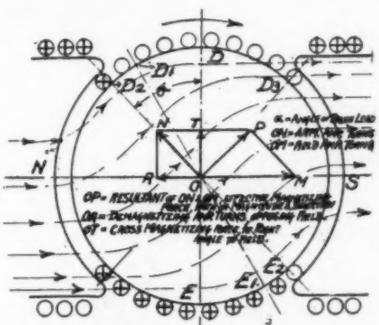


Fig. 5 — DISTORTED MAGNETIC FIELD — MACH. (MOTOR) AT FULL LOAD D. BRUSH POSITION D & E2.

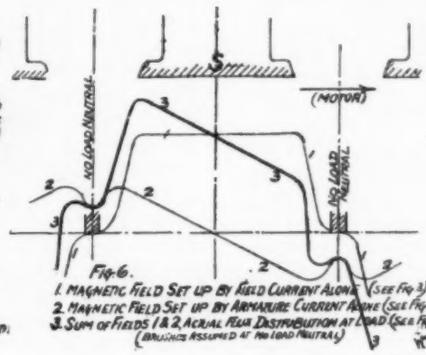


Fig. 6.
1. MAGNETIC FIELD SET UP BY FIELD CURRENT ALONE (SEE FIG. 3)
2. MAGNETIC FIELD SET UP BY ARMATURE CURRENT ALONE (SEE FIG. 4)
3. SUM OF FIELDS 1 & 2, ACTUAL FLUX DISTRIBUTION AT LOAD (SEE FIG. 5)
(BRUSHES ASSUMED AT NO LOAD NEUTRAL)

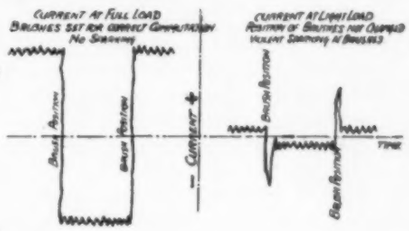


Fig. 7.
— FACSIMILE OF OSCILLOGRAM OF CURRENT IN ONE ARMATURE COIL IN NON INTERPOLE MACHINE — FULL LOAD A, LIGHT LOAD — BRUSHES NOT SHIFTED.

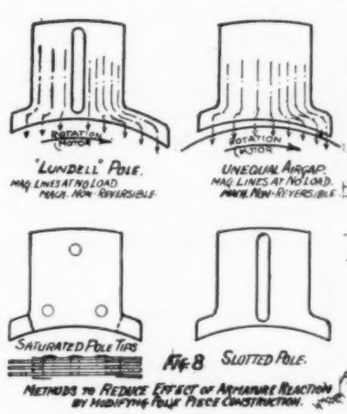


Fig. 8
METHODS TO REDUCE EFFECT OF ARMATURE REACTION BY MODIFYING POLE PIECE CONSTRUCTION.

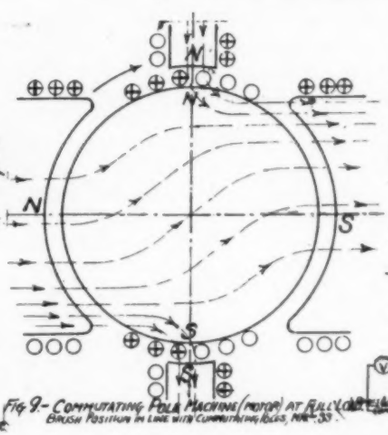


Fig. 9 — COMMUTATING POLE MACHINE (MOTOR) AT FULL LOAD
BRUSH POSITION IN LINE WITH COMMUTATING POLES, NA—SS.

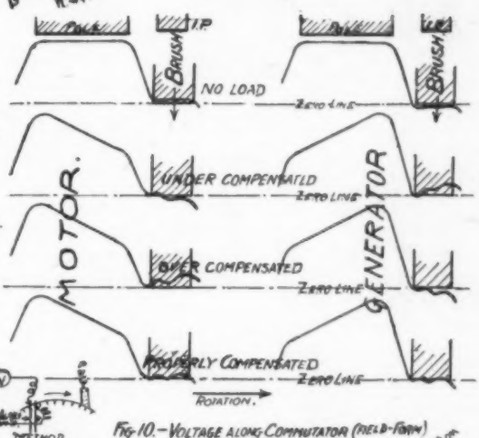


Fig. 10 — VOLTAGE ALONG COMMUTATOR (FIELD-FORM)
(INTERPOLE MACHINE)

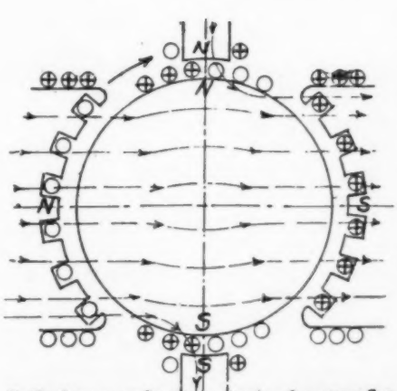


Fig. 12 — COMMUTATING POLE MACHINE (MOTOR) WITH COMPENSATING FIELD
BRUSH POSITION IN LINE WITH COMMUTATING POLE, NA—SS.

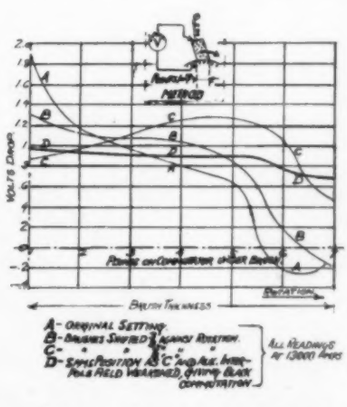

METHOD
VOLTS DROP
BRUSH THICKNESS
ROTATION
A — ORIGINAL SETTING
B — BRUSHES SHIFTED AGAINST ROTATION.
C — "
D — SAME POSITION AS C, BUT POLE PIECE FIELD WEAKENED, GIVING BLACK COMMUTATION
ALL READINGS AT 13000 AMPS

Fig. 11 — "BRUSH DROP" CURVES 3300 KW 250 VOLT REVERSE.

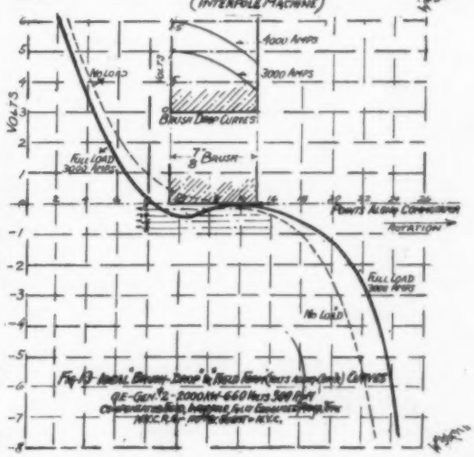


Fig. 13 — RADIAL BRUSH DROP & FIELD FORM (BOTH ARMATURE) CURVES
GE—GEN. "2" — 2000 KW—660 VOLTS 300 R.P.M.

given much broader effect. Suppose the main winding on an interpole were increased 4% and a shunt winding of 4% strength put on in opposition to main winding. The actual effective ampere turns at full load would be 15% as before but at ½ load they would be 5½% instead of 7½% as before and at 100% overload they would be 34% instead of 30% as before. This changed condition could be used effectively to overcome saturation in interpole etc.

The polarity of interpole field is the same as main pole back of it for a motor and main pole ahead of it for a generator.

Rotaries starting from AC side must have a device for lifting brushes off commutator during starting period to avoid burning from effect of revolving field (Same reasoning as above).

Interpoles do not prevent field distortion as assumed erroneously at times. As a matter of fact they increase armature reaction slightly and tend to weaken motor field (increase speed) and weaken generator field (decrease voltage) even with brushes in their normal correct position. If brushes are given a slight lead (**against** rotation in motor, **with** rotation in generator) this influence is much more pronounced and may become troublesome by causing **hunting** in motor and **unstable** operation in generator. (The remedy for these difficulties is to give motor brushes a slight lead in direction of rotation or move generator brushes slightly against rotation).

COMPENSATING FIELD. The points touched on in above paragraph are the principal reasons for using a **compensating field winding** in addition to Interpole winding on many large machines and some small machines of special application. Fig. 12. The compensating winding is in series with armature and interpole winding. It is laid into slots in pole faces and neutralizes the armature field whole or in part according to its design. The present practice seems to be to use about 70-80% of the armature ampere turns for the compensation. Armature reaction is correspondingly reduced and the voltage curve along commutator at full load is not materially different from no load. Fig. 13 shows both "brush drop" and "field form" curves of a modern generator having both compensating and commutating fields.

The principal advantages gained by compensating field design are—

Machines respond more readily to load changes (since armature self-induction is also reduced).

Flashing over due to heavy load changes is less frequent, armature reaction being small.

Interpole winding may be reduced by allowing for the compensation already provided for in compensating field. The resultant reduced winding will give a better ratio between effective and leakage flux of interpole since the latter are a function of total excitation and not of effective excitation only.

ARMATURE WINDING EQUALIZATION. Practically all large machines with 4 or more poles have parallel (lap) wound armatures where the armature circuits are paralleled by the brushes. The currents do not divide equally in all circuits for several reasons. To begin with, the brush drop the principal compensating factor, varies. The field strength is not the same under all poles (variation of air gap, inequality of magnetic properties, etc). All this affects division of current adversely. It causes circulating currents which interfere with commutation. To help this condition **equalizer windings** have been used in parallel wound armatures for many years. Originally 4 rings were standard, each connected to as many points on armature as the machine had pairs of poles. The equalizers tend to balance the circuits by carrying circulating currents which react on the field and correct inequalities therein. The tendency has been to gradually increase the number of equalizers until at least one coil in each armature slot is thus connected. Large machines cannot be run without these windings. Within the last few years a simple arrangement of the commutator tangs has been devised by the large manufacturers which eliminates the separate equalizer winding and gives perfect equalization by connecting each commutator bar with all of its equipotential bars in the machine. The arrangement is simple, instead of carrying the commutator tang radially to the nearest armature coil the tang is made in two parts, one section connects with a coil to the right and the other section with the nearest coil of same potential to the left, see Fig. 14 and 14A. Commutation is much improved by this feature. The equalizer winding with its drawbacks is eliminated.

DOUBLE BRUSHES. The Crocker Wheeler Company some years back advocated a **composite** brush (built in layers). Lately much improvement in commutation has been brought about by the revival of **double brushes,** two of ½ thickness, separated by a barrier in place of the single large brush. Mr. Lundell of the Sprague Electric Company foresaw the advantages of this construction some 25 years ago, but only within the last five years has the demand on equipment forced this improvement to the front. Fig. 15 shows a simple construction employed by the Westinghouse Company.

The principal reasons for improvement of commutation by means of double brushes may be laid to the following facts:

Contact between brush and commutator is constant and uninterrupted, being maintained by one brush or the other, since they probably do not vibrate in synchronism.

The cross resistance of the double brush is high as compared with that of the single brush.

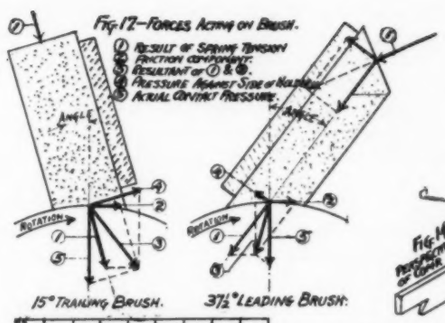
The inertia of each brush is lower than the original single brush.

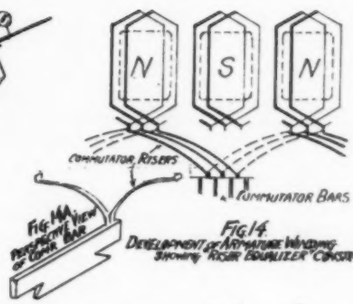
It is likely that considerable higher densities may be used with smaller brushes. Perhaps also lower contact drop material may be applied. The double brush idea offers a fertile field for further improvements.

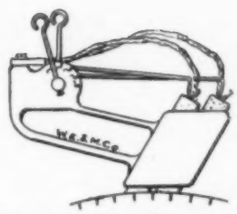
BRUSH RIGGING AND BRUSH HOLDERS. In order that a brush operate properly it has to make continuous physical contact with commutator, and the statement that over 50% of all brush troubles are purely mechanical may seem exaggerated, but it is probably true. Assuming most modern brush holders to be of the sliding box type, assuring contact with commutator at a certain specific point independent of wear of brush, the following features must be met:

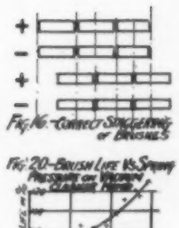
Simple adjustment should be provided so all holders can be rocked simultaneously to a new position and locked there preferably.

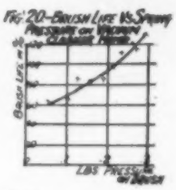
Individual adjustment of each brush range and each holder in a radial direction is necessary to take care of reduction in commutator diameter and to

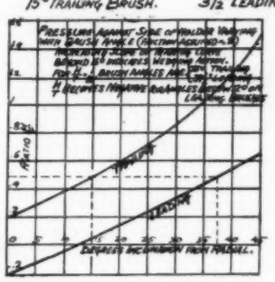


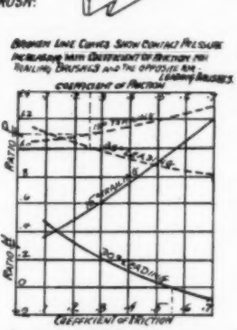


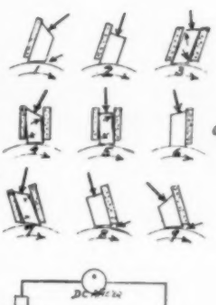







Pressure Against Side of Holder Varying with Brush Angle (Friction Against Holder)
Trailing
Leading
Brush Angle
Degrees Inclination from Radial.


Brown Line Curves Show Contact Pressure Increase with Decrement of Friction for Trailing Brushes and the Opposite for Leading Brushes.
Coefficient of Friction
Ratio P/F
Trailing
Leading
Coefficient of Friction
Full Line Curves Show Changes in Brush Pressure Against Side of Holder with Changes of Coefficient of Friction. Increased Friction in Trailing Brush Moves Increased Side Pressure the Opposite Applies to Leading Brushes.



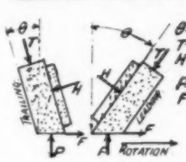
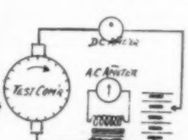
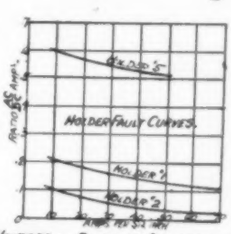
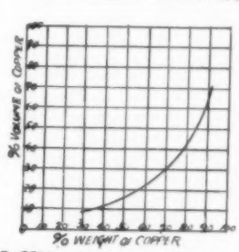


Fig. 18—Influence of Rotation, Angle & Friction on Brush Performance.







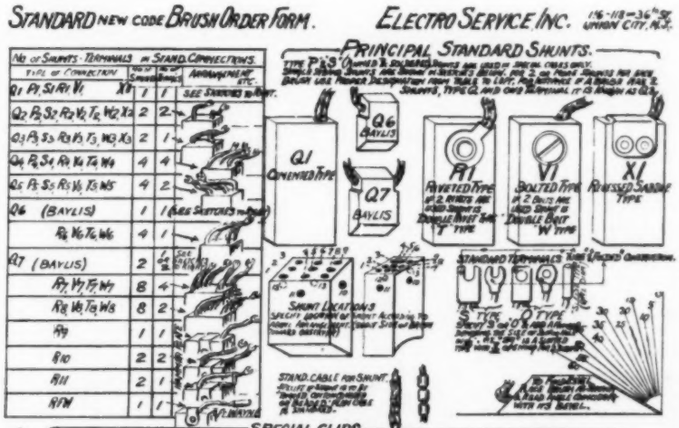
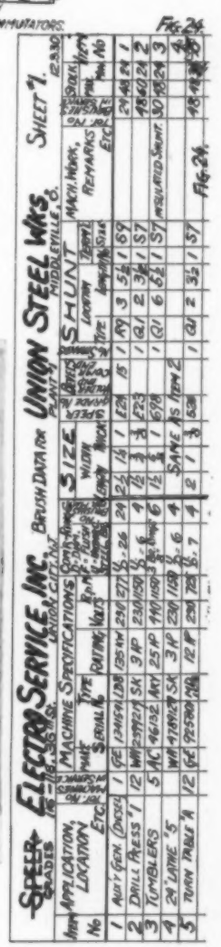


Fig. 23.



keep brush box within one-eighth inch of commutator surface.

Brush arms must be so supported or constructed as to be free from vibration at all points over commutator length.

To avoid unbalancing of brush arms the current should be carried from brush through rigging to outgoing leads by a copper conductor all the way with as few joints as possible, avoiding other metallic conductors which may oxidize at joints, etc.

To reduce vibration brushes must be as small as economy will allow. This will make their momentum lower, they will dissipate the heat better, and they may be rated higher.

To prevent interference provide individual boxes for each brush, relatively deep and if possible with uninterrupted surfaces to prevent imbedding of brush.

To insure even commutator wear stagger brushes so that both positive and negative brushes sweep all parts of the commutator. This is best accomplished by allowing brushes on two adjacent arms to follow in each other's tracks, while next 2 arms are staggered with reference to the first pair, see Fig. 16.

To insure quiet running radial brushes must be avoided except on small sizes and for strictly reversible service. Top bevel, face bevel and spring pressure must be so arranged that either entering side or leaving side of brush is held against holder with moderate pressure and brush is free to move under existing conditions of speed, friction, and eccentricity of commutator.

Figure 17 illustrates 2 most popular holders, the 15° trailing and the 37½° leading (reaction) type with elementary deduction of all actions and reactions resulting from spring pressure.

Figure 18 (by Warren C. Kalb, formerly Works Manager, Corliss Carbon Company) shows by analysis that 15° in trailing brush and 37½° in leading brush are not mere accidental values but are well chosen to meet the requirements set down as above. Particular attention is called to the fact that for a friction coefficient of .2 the pressure H against side of holder is about ½ of the spring pressure T at 15° trailing and 37½° leading. It may also be noted that for angles larger than 15° the trailing brush will "wedge" due to rapidly increasing pressure against side of holder.

A highly interesting investigation was made by the Ringsdorff Co., (Mehlem, Germany) based on the fact that most commutators run perhaps slightly eccentric. The various holders were classified according to their ability to allow brushes to follow the eccentricity of commutator. Consider the 9 possible designs 1 to 9 in Fig. 19. It is evident that holders, 1, 8 and 9 do not allow brush to make continuous contact at its leaving edge. Holders 3, 4, 5 and 7 cause a wedging action of brush in box. Only the remaining holders 2 (reaction) and 6 (radial) hold out promise of results and were investigated with reference to the "rocking" action necessary to follow commutator. Sketches 10, 11 and 12 show holder 2 in three characteristic positions. For position 10 the brush must rock around point A. (OC must be greater than friction OD and EF must not interfere with action of OC). For position 11, normal position of commutator, brush must lean against face AB (OC still greater than OD). For position 12 brush must rock around point B (OD must now be larger than OC, etc.) For a friction coefficient up to .3 the following limiting values give aforesaid results:

Length of brush not over 1.82 times thickness.
Brush angle at A not over 73° approx.
Brush angle at B not under 76° approx.

Similar limits were determined for holder profile #6. To verify the values thus calculated an eccentric commutator was tried with holders #1, 2 and 5. A D.C. Ammeter in circuit measures the current supplied by battery as shown in diagram. A transformer in circuit is connected through its secondary to an A.C. Ammeter. The ratio of A.C. to D.C. amperes was noted with commutator in operation. Curves show the result of observations. Holder #2, patterned after the above limits showed no sparking, followed the motions of commutator and showed practically no A.C. readings; whereas holder #5, (our often used radial type) sparked profusely, and showed a large percentage of A.C. current. Observations with a stroboscope disclosed that the sparking occurred when leaving edge of brush was not in contact with commutator.

BRUSH PRESSURE. Springs of the clock or similar type are desirable so that a small amount of brush wear will not change brush pressure materially. Enough points of adjustment must be provided to make up for brush wear. Some successful efforts have been made lately to provide micrometer adjustment in a simple way between main points of adjustment. During the whole life of brush the pressure per square inch should lend itself to adjustment for:

2 lbs. and over for carbon and graphite
4 lbs. and over for metallic brushes
6 lbs. and over for railway brushes.

Pressure on brushes is the most important single item affecting performance which may be controlled by operator at will. The pressures used in practice are too low rather than too high. A heavy metal brush needs higher pressure than a lighter carbon. In adjusting pressure, allowance has to be made at times, for the weight of heavy slip ring brushes which add to or subtract from spring pressure according to their location on ring. Fig. 20 shows results of tests on vacuum cleaner indicating life of brush almost proportional to spring pressure.

BRUSH SHUNTS AND TERMINALS of proper proportion are essential. All brushes used in sliding box holders should be provided with strong shunts of uniform and low resistance at point of insertion not affected by temperature and constant vibration. Detachable shunts involve many risks and have almost disappeared. Large saddle type of connections are not particularly desirable. While adding to weight, they do not give relatively lower drop. The two remaining types, the cemented Q, and the plain riveted R or Bolt V have become standard (designation according to new code by NEMA). The type Q or insert type is to be recommended wherever possible. The uncertain item of solder is eliminated by it, expansion under heat does not affect it greatly. Its capacity has a great range because up to 4 or more shunts may be used on one brush. It withstands vibration fairly well if properly made. Where hammer plates are needed, they may be attached separately and will not transmit the vibration from hammer as is the case when they are made up as part of the riveted or bolted type connection. Cer-

tain improved bolted type and molded-in pigtails have lately been brought out and show promising results.

Manufacturers have been criticized for too small or too large a shunt connection. This criticism is not always in order. The size of shunt does not depend entirely on the current it carries. Larger shunts are often put on to carry away the heat. Smaller shunts than standard are used when the size of shunts interferes with operation.

Terminals are by no means unimportant. They should in some measure conform in size to the currents to be carried. They should be fastened preferably to the copper conductor which carries current through brush rigging, and in no case to attaching screws holding boxes in place. Specify terminals of the folded or tube type. They are by far the best. The strands of shunt are sheathed in a copper conductor directly under screw head. Avoid special terminals which may have been quite in order in their day but are not so now and are a cause of unnecessary expense to the manufacturer of brushes.

RAW MATERIALS THAT ENTER INTO THE MANUFACTURE OF BRUSHES:

Petroleum Coke—carbon left in petroleum stills. Pressure still type or tower still type.

Retort Coke—a coal tar product which condenses in the stills of certain types of gas generators.

Lampblack—deposited on condensing surfaces when oil is burned under restricted combustion.

Natural graphite—flake type as mined in Ceylon, Madagascar, Mexico, etc.

Artificial graphite—graphitized carbon flour amorphous shape.

Various binders—pitch, tar, molasses, phenol binder (all non-metallic). Tin, lead, zinc, and antimony (metallic binders for alloy type of copper graphite brushes).

Copper powder—pure copper powder up to 300 mesh and over, reduced from metallic copper or copper oxide.

MANUFACTURING PROCESS. Brushes are molded and baked. The molding process having gradually replaced the less desirable extrusion process. The baking range covers temperatures up to 2500°C. A homely but striking analogy is to compare brush making with the making of bricks. A general idea of the intricate process of making carbons was gained from a very instructive film "Behind the Pyramids" shown by the National Carbon Company recently. In some cases it takes up to 12 weeks of continuous processing to produce material, and all that can be pointed out here is the fact that control of the various operations involves much investment in research, labor and apparatus. A "Production Control Chart" taken from page 7 of Speer Catalogue No. 24 gives an idea of the many items involved. Fig. 21.

A CLASSIFICATION OF BRUSHES. The operating man is helped materially by keeping in mind the general nature of a brush. Each class of material is capable of producing certain specific results which cannot be greatly varied or extended no matter how made and processed or by whom. The difficulty, experienced in actual application, is often camouflaged by substitution of other classes of material instead of modification in the same class. The new material may remedy the difficulty but is liable to have shortcomings in other directions which may or may not be equally objectionable but which will not be in evidence until some time later on. This is another reason why all brushes should carry the manufacturer's original grade number. This will expedite the process of eliminating obsolete grades and make for a lesser number of standard grades.

Carbon and Carbon Graphite Class. These brushes belong, perhaps, to an earlier period than the others. Some are made from various forms of carbon. Others have various proportions of graphite added to vary resistance, contact drop, etc. Baking temperatures cover a range up to 1000°C.

While this class may be described in general as moderate in cost, fairly abrasive, medium capacity not suited for high speeds, there is entirely too little attention paid to them by both the manufacturer and the user. As we become more acquainted with the so-called high grade brushes, we find that material in the carbon class often does work which we do not give it credit for.

Electro Graphitic Class. (Also known as graphitized carbons). The regular carbon is subjected to a temperature up to 2500°, while the air is excluded. This is best accomplished in a graphitizing furnace (electric furnace). The heat drives out nearly all abrasive and volatile matter, brush plates actually shrink under this process. The final product is a non-abrasive, high capacity carbon, especially adapted to high speed heavy duty work on undercut commutators. Partially graphitized material using either lower temperature or less time for process retains some cleaning action but general practice seems to indicate that brushes of this type have other shortcomings.

Graphite Class. Pure, mined flake graphite with tar, pitch or phenol binder and brought up to 500°C. max. approximate temperature makes up this class. In some cases copper powder is added to strengthen mechanical structure. Graphite brushes are very low in hardness and friction. They generally give good brush life on account of the hard glaze that forms on face. They are therefore well adapated to extremely high speeds. They are mildly abrasive when their ash content is around 2% and more so with increase of ash. This is why they keep a cleaner commutator in general but wear it somewhat in time. The flake graphite structure gives them a high cross resistance which aids commutation, but it is a disputed question whether they are as reliable for heavy duty as the graphitized carbons since their structure is affected by continuous high heat.

Metal Graphite Class. Brushes in this class contain copper in various proportions from 40 to 90% by weight. Sub-division is as follows:

Alloy type. When copper powder of the pure or oxide type 85% by weight and over is mixed with some graphite and a binder of tin or lead and baked at temperatures up to 800°C. we obtain an alloy brush. It is readily made, mechanically strong, has high capacity and low drop of .18 to .25 volts per polarity.

It is fairly abrasive, long lived because its structure is more like that of a casting. It is used on medium speed composition rings, platers, etc.

Non-alloy type of brushes use non-metallic binder, graphite and copper powder, the latter varying from 60 to 85% by weight. The baking process is much

PROPERTIES OF BRUSHES

Item	DEFINITION (General and Specific)	EFFECT, VARIATION, Etc., Etc.
Resistance	Opposition offered by material to flow of current. Specific resistance is ohms per in. cube of material from one face to opposite one.	I^2R loss due to resistance is low—therefore resist. Not important except by its influence on contact drop. Increase in temperature lowers resistance (neg. temp. coefficient)—ratio of crosswise to lengthwise resistance affects commutation.
Capacity	Current a brush carries without undue heating. Normal capacity is given in amps. per sq. in.	Capacity of a brush is largely governed by thermal conductivity and refractory qualities. Amps. density in a brush is a complex quantity and influenced by commutation—loads of uniform nature such as slip ring and contact work may be rated 25% to 50% above.
Contact Drop	Voltage needed to pass current from brush to current carrier. Normal contact drop is the voltage when normal current is passing. Total drop is the sum of pos. and neg. drop.	Most important property affecting commutation, neg. drop higher than pos. (generator sense). Varies according to deposit on commutator. Varies with current, but at lesser rate and finally becomes nearly constant. Varies with speed but at much smaller rate. Goes down slightly as pressure increases. (Air pressure under brush affects it.)
Friction	Force opposing motion of contact surface. Under brush. Coefficient of friction is ratio between force of friction and normal pressure at surface.	Low friction is essential. Friction not proportional to abrasive action. Friction dependent on air pressure under brush and on deposit on commutator surface. Friction at load less than at no load (see Fig. 25). Coefficient of friction goes up with pressure and down with increase in speed.
Hardness	Ability of surface to withstand pressure. No absolute measure for it. Scleroscope hardness measured by height of rebound of a steel weight dropped from a certain height.	Must not be confused with abrasiveness. Has influence on strength of brush and vibration of same. Scleroscope hardness depends on type of finish given to surface.
Strength	Ability of material to withstand mechanical strains. Transverse strength is given in lbs. per sq. in.	Strength needed where severe mechanical shocks are met with. Strength like hardness is influenced by materials used, pressure in molding, temp. in baking, etc.
Abrasiveness	Polishing action of brush on contact surface. No specific measure is used for it, except indefinite terms—high—low—medium.	Not influenced by hardness. Influenced only slightly by friction. Percentage of ash in brush is a close indication of its abrasiveness—is required where heavy overloads occur. Seems smaller at heavy loads than at light loads.
Musical Sound	Musical pitch of note given out when brush is struck a blow while supported by non-sound absorbing means. No definite measures established except by Westinghouse Laboratory.	Important in selection of brushes against mechanical failures, and probably indicative of many other properties.
Porosity	The percentage of pore space in brush. To determine it divide the difference between the real and apparent density by the real density.	Very important to manufacturer to check the various processes of baking, grinding, molding, etc. Excessive porosity claimed responsible for undue absorption of moisture and subsequent breakage with sudden temp. changes.
Structure (Micro)	Distribution of various materials in a brush and its texture is best seen by micro photo of face of brush.	Important to manufacturers to determine strata, layers, impurities, etc., where other tests fail.
Max. Speed	Max. permissible speed in feet per minute of contact surface under brush is usually given.	Rather arbitrary limit. Angular speed of equipment (r.p.m.) seems more important since impulses imparted to brush by eccentricity of commutator are proportional to r.p.m.

PRESSURE—INERTIA—THERMAL CONDUCTIVITY—IMPURITIES Referred to in Text.

longer and temperatures are much lower, say 400°C. According to their copper content these brushes are known as medium metal 60 to 80% copper by weight, contact drop per polarity about .6 to .3 and high metal 85% copper and over with contact drop of .25 to .2. These brushes are less abrasive than the alloy type. They are not as strong as the alloy type mechanically however, they may be used on platers and high speed rotaries, etc., at ratings from 80 to 125 amperes per square inch.

Low metal type. Carbon or graphite brushes "Copper Impregnated" or "Metallized" by a patented process are the principal representatives in this class. Copper content varies according to porosity of original material and reaches nearly 60% by weight in some cases. Contact drop as low as .7 volts per brush. The almost entire absence of dusting and abrasion makes these brushes highly desirable on small high speed rotaries where the density does not exceed 80 amperes approximately and where there are 4 or more brushes per ring. This material is also used to advantage on low voltage commutators ten to eighty volts and over.

Attention is called to the fact that since the % of copper is given by weight the % of volume of copper when combined with graphite of 1/5 the weight is much lower but more important to operation, since the contact drop is probably proportional to the volume of copper and not to the weight, see Fig. 22.

(It is also in order to mention copper gauze brushes here although they are almost obsolete and outside the sphere of this discussion. Their shortcomings are well known but it is not generally understood that their contact drop is lower than the high metal brush and commutation is good, principally on account of the high cross resistance of the fabric. Replacing these brushes with metal graphite is oftimes a problem).

SELECTION OF GRADES

Equipment	Grade
Medium and high speed heavy duty generators or motors with undercut mica.	Electro Graphitic brushes fully non-abrasive.
Medium and high speed heavy duty generators and motors with undercut mica and periodic overloads.	Electro Graphitic brushes with cleaning brushes distributed over commutator or graphite brushes with 2% or less ash.
Cranes, hoists, etc., with undercut mica.	Carbon graphite brushes with slight cleaning action or as second choice semi-graphitized carbons.
Cranes and hoists with flush mica.	Carbon graphite brushes with considerable cleaning action.
Heavy duty mill motor service.	Carbon graphite brush of fine dense structure with considerable cleaning action.
Turbine field rings, steel.	Graphite brushes with considerable cleaning action, light binder and low inertia.
Rotary slip rings.	Low metal brushes on high speed small sizes up to 500 KW., 250 volts and 1000 KW., 600 volts if more than 4 brushes per ring. Medium metal brushes of a non-alloy type on high speed rotaries 1000 to 2000 KW., if density is suitable. High metal brushes of a non-alloy type on large machines 2000 KW and over (alloy brushes only on older machines of slower speed).
Induction motor slip rings.	Use metal brushes only where service demands it. Low friction graphite on large machines with many brushes per ring. Electro graphitic brushes on smaller machines with fewer per ring.
Controllers, contacts, etc.	A hard and dense, low resistance carbon.

HOW TO ORDER BRUSHES. In addition to the difficulty of finding the right grade for your equipment the brush makers greatest trouble is to know exactly what you want in size, bevels, etc. You can help this situation by furnishing proper specifications. Uniform terms have now been agreed on by the carbon brush section of NEMA. Any new brush catalog will disclose them.

The letter Q stands for the cemented shunt.
The letter R stands for the riveted shunt.
The letter V stands for the bolted shunt.
The letter X stands for the recessed saddle shunt.

A, B, C, D, E, F, G, H are various types of lifting clips.

Positions 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 give different locations of pigtails.

S stands for slotted and O for ring type terminals. A figure that follows denotes the opening in 32nd in. S9 therefore is a slotted terminal with 9/32" opening and may properly be used for ¼" screw.

It is comparatively easy to specify any brush by filling the spaces in at bottom of sheet "Standard, New Code, Order Form"—Fig. 23.

Since the nomenclature applying to brushes is now uniform, thanks to the united efforts of government and brush manufacturers, it is recommended that the "Condensed Brush Data"—Figure 24—be made up by the user himself to cover all of his equipment. Blanks may be obtained from any brush manufacturer. The writer has used these sheets for over 12 years. They are readily filed because of their

letter size; they contain up to 30 items each and all item Numbers are consecutive, beginning with No. 1. Property Item numbers or any other designations appearing on records may be used in place of plain item number. A certain brush is only specified once and thereafter if used on other equipment referred to "Same as Item No. —". This helps to reduce the number of sizes. Where quantity of brushes or importance of equipment warrant carrying a stock, the sheet may be so marked under "Maximum" and "Minimum" in "Stock" column. Originals are held on file at the Electrical Department, copies at the Store Room or Purchasing Department. Additions and changes are readily made and carried through the records. In this manner a co-ordinated system is maintained, avoiding much confustion, duplications, excess of stock, improper specifications, etc.

In conclusion it may be stated in all fairness to the brush manufacturer that in view of the technical points involved in the application of his product his status is not an enviable one and admittedly the ultimate profits of his business are anything but large. Brushes, commutators and rings are the only parts of a machine where appreciable visible wear must of necessity take place, for a modern unit at 10 hours per day and 300 days per year may have a total commutator travel of 180,000 miles per year. No wonder that the result is apt to be a point of controversy. Conditions may arise in the operation of equipment for the effects of which the brush maker should not be held responsible. He is not a Sherlock Holmes. Many phenomena take months to develop. On the other hand the brush maker has always been willing to provide well trained men for the solution of any problems which may arise. Unfortunately these men, mostly for want of moral support, have not always been able to analyze the problems and define them as machine, brush, condition problems or a certain combination of these. Taking it all in all, an impartial observer must come to the conclusion that the greatest good in the brush field may be derived from a closer approach of the equipment manufacturer and brush maker on all disputed points, so that the user may be assured a definite performance.

DISCUSSION

Discussion Presented by

K. M. Raynor, Philadelphia, Pa.
F. O. Schnure, Electrical Supt., Bethlehem Steel Company, Sparrows Point, Md.
P. D. Manbeck, Advisory Engineer, National Carbon Co., Inc., Cleveland, Ohio.
J. V. Dobson, Chief Engineer, Stackpole Carbon Co., St. Marys, Pa.
H. D. Esterly, Electrical Supt., Alan Wood Steel Company, Conshohocken, Pa.
L. A. Heath, Technical Manager, Morganite Brush Co., Inc., Long Island City, N. Y.
A. S. Bemis, General Supt., Speer Carbon Co., St. Marys, Pa.
J. S. Marcus, Sales Mgr., Electro-Nite Carbon Co., Philadelphia, Pa.
H. H. Angel, Williamsport, Pa.
J. Bourath, Electrical Engineer, Electro Dynamic Co., Bayonne, N. J.
W. Siebenmorgen, President, Electro Service, Inc., Union City, N. J.

K. M. Raynor: Before the discussion of Mr. Siebenmorgen's paper, I want to make mention of the rather specific set of questions which Mr. Siebenmorgen has prepared and which will be shown on the screen and presented by him for open discussion after the discussion of the main paper.

F. O. Schnure: This discussion reminds me of one of the first times I took my eldest boy to the movies. We happened to get inside the picture house at the time the orchestra was playing an interlude. This took up so much time that the boy became impatient, and said to me, "I didn't come here to listen to the band!"

With all this talent here, including brush manufacturers and salesmen, what I have to say may be considered as an interlude. We fellows in the steel business, complain a great deal about the brushes used on some applications. With some exceptions, I believe we have almost the same grade of brushes on mill type motors that were used ten years ago. At that time we had more flat spots on our mill commutators than we have today, because undercutting was not a general practice. However, I think our greatest problem is on our special machines, not on the motors but generators. Generators on blooming mills are called upon to carry very heavy overloads. The fact is, the overloads and abuse that a reversing equipment will get will depend largely on the operator. Out of three rollers, one will abuse the equipment more than the other two. The motors are generally large, slow-speed machines, and give very little trouble. We have invariably blamed the brushes for generator trouble and in 75% of the time, possibly, we have been wrong. When the situation was analyzed we usually found mica trouble. Maybe one or two high micas here and there, which finally gave us flat spots and trouble of a very vital nature.

In looking at Mr. Siebenmorgen's curves here, it struck me that the designers of the equipment might be able to furnish us with a statement of the commutating conditions the brush must master; that is, here is a generator that commutates under condition A, we will say, and then if we have (X) manufacturer's brush on that machine and it does not work so good, we can try (Y) manufacturer's brush on that machine by referring to condition A. On second thought, I do not know whether that is possible or not, because those conditions will change with the setting of the brush rigging, etc. Anyhow, here is the bad situation in applying brushes to electric machines: If we are not satisfied with the brush in service and we will first allow the brush manufacturer to try another grade. Maybe it will

work good, and again it may not. Then we try a brush that another manufacturer thinks will do the job—and possibly won't. It is a very embarrassing position to take a mill out of production for four or five hours to change a set of brushes during the week, and we have had that happen time and time again in our plant. When a machine cuts up badly, we ought to be able to pick from any of half a dozen manufacturer's, the proper brush to do the job by naming the condition under which the brush is to operate and without resort to the trial and error method of application.

P. D. Manbeck: I should like to emphasize several points which Mr. Siebenmorgen brought out so ably in his excellent paper. The question of friction as related to brush angle is coming to the forefront more than ever at the present time since many reversing mill MG sets are running idle for a part of the time. It is a well known fact that the co-efficient of friction of carbon on copper rises con-

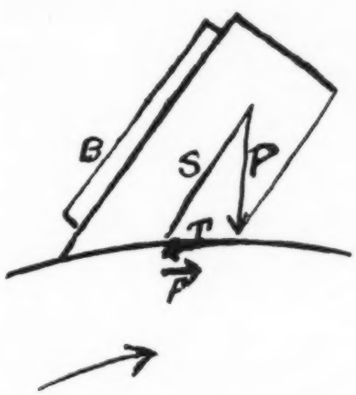


FIG. 1

siderably when no current flows between the contact. This fact will explain many cases of chattering on machines operating under reduced load whereas the brushes under normal conditions carrying load operate with practically no noise.

In the figure shown above if "S" represents the spring tension, "P" the normal component holding the brush on the commutator, "T" the tangential component tending to hold the brush in a stable position against the side of the box "B", then it can be seen if "F" the friction increases to the extent that it equals "T" there will then be no stabilizing action and the brush will vibrate between one side of the box and the other resulting in the familiar chattering action which tends to make shunts and hammer clips become loose and break. As long as normal current passes between the contacts the co-efficient of friction remains low and the force of friction "F" never equals the tangential component of the spring tension "T" thus insuring a stable operating condition.

If the cycle of operation cannot be changed and it is found that the generators must run for relatively long periods without any load the co-efficient of friction can be decreased by the addition of so called graphite "cleaning" brushes which should be staggered about the commutator in such a fashion as to sweep the surface completely with every revolution. If more action is necessary, twice the number of cleaning brushes mentioned before can be used and these should be installed on the negative studs of the generator unless the polarity is continually changing, in which case any studs will serve the purpose.

Cleaning brushes also serve another purpose:—In several cases where difficult commutating machines are met with, the commutators have a tendency to blacken or burn at the edges of the bars. In such cases the addition of cleaning brushes usually solves the problem. The life of the main set of brushes is usually increased somewhat by this same means. Several grades of cleaning brushes are available and if a difficult amount of cleaning action is necessary on several machines this can be secured by selecting the proper grade and then by varying the quantity of brushes staggered in. In this manner, almost any desired amount of cleaning action can be secured.

I feel that too much cannot be said on the subject of brush pressure. When a set of brushes is installed on a machine the recommended spring tension is usually applied. However, as the set wears down it frequently happens that the spring tension is not increased sufficiently often to follow the brush in the box and some of the brushes make only indifferent contact with the commutator. This most generally results in selective action which burns and blisters the bars and wears away the brushes rapidly. Firm contact with the commutator is necessary to insure that the brushes carry the load without excessive heating and sparking. Two to two and one-half pounds per square inch is usually sufficient for an electrographitic grade on a high speed commutator traveling 5300 feet per minute provided the brushes are kept free in the holders.

J. V. Dobson: In reading the advance copy of Mr. Siebenmorgen's paper I found myself taking rather strong exception to the first page of the paper. I felt that Mr. Siebenmorgen had ascribed to the steel manufacturer, to the copper manufacturer and to the manufacturer of insulation, a definite credit for being abreast of the time in machine development. But to the carbon manufacturer he did not assign such credit. However in listening to Mr. Siebenmorgen's very able paper and his amplifying of that paper I now am very sure that that criticism does not apply and I feel that the whole subject has been handled in a very fair manner.

Modern electric machine design has reached its present stage of development by systematic continued and persistent effort to improve all the component elements of the machine. The steel manufacturer has responded to the demand for better steel, less losses and higher permeability and higher mechanical strength. Copper has been improved so that today it is 99.8% pure. Insulation is at a very high state of perfection as compared to the insulation of earlier days. Carbon for brushes has been improved as indeed must be to be applicable to higher speed machines of present day practice.

In some respects however, modern electric machine design has simplified the brush problem. This is particularly in reference to improved commutator constructions and to the use of the double brush brushholders. Commutators are more accurately designed against the stresses of centrifigal force and of expansion. Commutators are better processed and better seasoned. Therefore they keep their shape better under service conditions. The result is smooth-

er commutators, better brush riding, better commutation, less brush breakage and chipping and longer brush life.

Similarly the double brush brushholder is a distinct improvement for the reasons given by Mr. Siebenmorgen.

The adoption of higher peripheral speeds renders a somewhat more difficult problem to the carbon manufacturer. Brush friction must be kept to minimum, brush riding characteristics must be improved so that the brush effectively rides the commutator in the face of the higher rubbing speeds. This emphasizes the need for lighter brush and a brush of higher resiliency factor. In connection with this latter the resiliency of a carbon brush (i.e. its ability to deform and restore its original shape under pressure) can be definitely measured and it is found that the notably good riding brushes are the ones on which the highest resiliency readings may be taken.

The problem of uniformity is probably the one most important to the machine operator. Certainly it is possible to reorder brushes with assurance of satisfactory duplication better today than was possible in the earlier years. This has been accomplished by establishment of accurate controlled processes. This problem offers still a fertile field for further research.

Mr. Siebenmorgen emphasized one point which also is in line with my own experience namely brush pressures should be higher rather than lower. It is my observation that more trouble is the result of too low brush pressure than of too high pressure.

H. D. Esterly: There are several things that have come to my mind. For instance, about twelve or thirteen years ago we purchased a motor and we got very poor commutation. We thought that the trouble was with the grade of brushes, and changed brushes, then changed the type of brush holders trying several different kinds, but did not get good results. Finally we had kind of a campaign on grinding commutators, and we ground the commutator of this armature right in the bearings. After that we had fine results.

Another thing Mr. Siebenmorgen brought out in his paper was the commutating poles. In winding armatures care should be taken as to the right connection of the leads to the commutator bars. Take a General Electric type G. E. 52 Armature, the commutator of which has 87 bars, this armature is wound with leads connecting to bars #1 and 44 and the motor does not have commutating poles. Another type armature a Westinghouse type MC frame #50 which has the same number of bars as the G.E. 52 but this armature is wound with leads connecting to bars #1 and 45 and the motor has commutating poles. The armature winder wound both armatures with leads connecting to bars #1 and 44, this made the Westinghouse armature run in the opposite direction to the way it should, when the motor was connected across the line, the commutating poles being connected right but the armature running in the opposite direction. The proper polarity of the commutating poles for a motor: proceeding from pole to pole around the frame in the direction of armature rotation, each commutating pole should have the same polarity as the main pole which just precedes it. The experience we had with this was that the brushes sparked, heated and burnt a ridge in the commutator as wide as the brushes. After correctly connecting the leads of the coils to the right bars in the commutator we had no more trouble.

I might add that we have found from our experience that the brushes are not always at fault.

L. A. Heath: First of all I want to congratulate Mr. Siebenmorgen upon the thoroughness with which he has covered his subject of brush performance. This has been done so well there is little left for me to do except to stress a few points.

Regarding brush pressure: the recommended pressures as given in the paper are quite standard but this note may be added, that very often certain conditions of operation call for a pressure different from that usually called standard. The real idea back of it all is to secure by means of pressure the best commutation, with the least wear on commutator and brushes.

When commutator surface speeds and current density permit, the use of the regular carbon grades are of distinct advantage where machines are subjected to oil leakake or oil vapors. Under these conditions carbon brushes are much less likely to smudge the commutator surface and will maintain a more constant contact drop.

Reference has been made to the relative ability of natural graphite brushes to carry heavy overloads. Within the range of usual overloads I think the natural graphite brush is superior to all other grades. When it comes to a real short-circuit on the unit, there is a point for dispute. Under these conditions the graphite brush will have shot away its entire contact face. Often this is considered a good trait, for then the brushes take the grief of the short-circuit, and no deep burning on the commutator results, as frequently happens when an electro-graphitic or carbon brush is being used.

As this evening's paper clearly brings out, the capacity of electric machines is being pushed higher and higher per pound of material. Because of this fact we must keep in mind the additional fact that practically all of the brush wear is due to current flow and by this I mean, not only the current that is registered on the meters but also the short-circuited current that is flowing in the contact face of the brush. There is really a transference of material in the direction of current flow. This fact is readily observed on collector rings of synchronous condensers when the ring of one polarity blackens and wears much more rapidly than the other.

We are coming more and more to realize that atmospheric conditions under which the units operate play a most important part in brush performance. In many of the manufacturing plants of today gases are present in the surrounding atmosphere that react on commutator and brush to produce a dark, high resistance film on the surface of the commutator. This film eventually causes commutation difficulties. Many troublesome cases of this nature are corrected by the use of the graphite brushes as described in Mr. Siebenmorgen's paper. And by the way, let us not be too hasty in condemning graphite brushes because of apparent commutator wear. In numbers of instances the wear seems great because of the reflections of a highly polished surface as produced by a graphite brush. The best way is to use a straight edge and try to measure the depth of the valleys.

Recently another operating condition which affects the AC brushes of a rotary converter more than the DC is the relative humidity of the atmosphere in the neighborhood of the unit. It has been found in a number of instances that when the humidity falls below a certain point unusual AC brush wear takes place. Some companies have gone to the expense of installing humidifiers to correct this condition.

In conclusion, I may say that for service on a modern motor or generator the selection of a suitable brush is often a difficult problem.

A. S. Bemis: After having listened to this very interesting paper delivered by Mr. Siebenmorgen and the discussion which has followed, I feel that something should be said in defence of the brush manufacturer, who, for quite good reasons, usually avoids participating in such discussions as this. To improve upon the excellent grades of brushes now to be found on the market, is not at all a simple matter.

We all appreciate the fact that substantially pure carbon seems to be about the only material that possesses the natural properties necessary for the making of high voltage dynamo brushes. Chemically, carbon is a simple element, and as such can hardly be expected to permit of very material modification. It is surprising, indeed, that enough allotropic forms are found to meet the requirements necessary to take care of all of the different machines a designing engineer can build.

To cite one example of the multitude of problems that confront the brush manufacturer, we will consider contact drop for a moment. This is probably the most important single brush property with which we have to deal. To secure good commutation on most high voltage machines, a comparatively high contact drop is required. This is quite easy to secure in itself, but unfortunately, contact drop and specific resistance go pretty closely hand in hand, so that to increase the former to the necessary point, so increases the latter that the brushes will no longer carry the load current necessary, without having their cross section or number increased. This, of course, would necessitate a larger and more expensive commutator and brush reading, and it would also increase power loss at this point.

As a matter of fact, a great deal of improvement has been made in brush manufacture in the past ten or fifteen years, and if the machine manufacturer had to go back to the old brushes now, he would soon appreciate this.

I do not wish to imply that there is no further room for improvement in brushes, for there most certainly is, and no one is more keenly alive to these possibilities than is the brush manufacturer. The condition of keen competition which exists between brush manufacturers, is in itself sufficient to insure us against any stagnation.

While nothing radical need be looked for in the near future, we may rest assured that the efforts of the various brush manufacturers will result in a constant and substantial improvement in grades.

J. S. Marcus: There is one point in Mr. Siebenmorgen's discussion that has a further interest. He spoke of the fact that some years ago Crocker-Wheeler worked on a double-brush, and it might be particularly interesting to note that this organization has recently done further work on that double brush, we having the pleasure of doing some research for them. In using two different brushes in the same holders, there is the difficulty of keeping equal pressure on the two brushes, one always taking the load. The problem was to make the two materials into a unit brush, and we finally managed to work out a cement to hold.

With regard to Mr. Siebenmorgen's remarks about graphite, we agree with Mr. Heath that it is the superior material on modern extra heavy duty equipment. It's one present drawback is low thermal conductivity, which will be overcome someday. Of course, it will have some abrasion as noted, because being a mined natural product there is a slight silica content, but good modern graphite may wear slightly yet not "cut." And one of these days some manufacturer of brushes will find an improved method of sorting out the raw material to get so low a silica content that will give a completely non-abrasive brush.

H. H. Angel: I have certainly enjoyed Mr. Siebenmorgen's paper tonight, and there is not much I can say about it, except that we have had our share of trouble with commutation on big machines which have been very greatly overloaded at practically all times.

I will say that the brush manufacturers have contributed their time very graciously, and we have cooperated with them to try out different grades of brushes to see if we could make progress in the life of a brush and a commutator. Of course sometimes our decisions on the merits of different grades of brushes have not been entirely correct or fair, as we know from experience that before a brush can be given a good test, the commutator must be as near perfectly round as possible and slots free from mica. Due to certain rolling schedules during busy times the latter qualifications are not always obtainable.

J. Bourath: I do not agree with Mr. Siebenmorgen that the compensator type of field winding is a cure-all. We have gone into this very thoroughly, and find that for medium size machines, it is a question whether the compensated field has much value, and for small machines it is proven that the compensated type of winding is both expensive, cumbersome and hard to maintain. What I mean to say is that the results obtained from the application of the compensating field on medium and small size machines do not justify its application on that type of apparatus.

The statements made by Mr. Siebenmorgen that much is to be done on the development of brushes are rather in order. We find that when we have a special application, it is difficult to get definite information from the brush maker, and when we have extreme designs, such as very high speed machines or enclosed machines of high rating, we are almost compelled to design the machine around a very cumbersome commutator. You can appreciate what I mean when you consider 175 HP running at around 5000 R.P.M. We have hardly any brush today that we would consider in line with the rest of the materials that go into the making of a machine of this type, and it must be remembered that machines of this type are coming into use more and more. While the standard brush gives fairly good satisfaction, the special grades we need for cases like the above fall short of our requirements.

The first thing we would want to see investigated is the increase of current desity in a brush used on equipment of the above type. That is the reason why we were somewhat interested in making a test for this lecture to demonstrate the feasibility of running a machine with half its normal number of brushes. While this test came through all right, it disclosed very little. All that we can say is that the machine was still on the test floor when we got through.

I want to congratulate the Association on the timely subject that they have discussed today. It is of interest to everybody, and there are ever so many points on which we need information.

Mr. Siebenmorgen prepared a series of questions to be discussed after the lecture. Because of lack of time he was asked to give his answers, which are recorded in short below:

Q. #1. When should lubricated brushes be used?
A. If at all possible avoid using them at all times. No lubricant or treatment is of a permanent nature.

Q. #2. When should "cleaning brushes" be used?
A. Where loads are extremely heavy it has been found expedient to resort to "cleaning brushes" in order to preserve a fair commutator surface. Graphite brushes of fairly high resistance with considerable ash content are used. Insert enough brushes on each brush arm so all parts of commutator are scoured. Use permanently or as occasion demands.

Q. #3. How to obtain same results as with Case #2, without danger of selective action.
A. Use a non-abrasive graphitized carbon on one polarity and a low ash graphite on other polarity.

Q. #4. How to reduce cutting by metal graphite brushes on composition rings without resorting to lubrication.
A. Use a low-ash graphite or a low resistance graphitized carbon without pigtails in one or more holder.

Q. #5. What to do after brushes have been moved to a different neutral point to improve commutation.
A. It is necessary to wait until brushes have attained a new face before permanent results are obtained. This will take hours or perhaps days.

Q. #6. Why older machines give less trouble from commutation than modern ones though—to use the popular term—"The density in brushes is the same."
A. Commutator speeds, both angular and surface, are higher and loss in watts per unit area of commutator surface is higher.

Q. #7. Which two features often improve older machines of medium and large size.
A. Reducing thickness of brush and providing equalizer connections or increasing their number.

Q. #8. How an old miner prevented brushes from spotting the rings of the synchronous motors on his M. G. Sets.
A. Transferred from the arduous work in the mine to a colliery substation he was told that rings had to be ground at such and such intervals because they would "spot". He followed instructions but observed that spots had the exact contour of brushes. After the next grinding operation, he made it his business to keep the brushes off rings while machines were shut down by inserting a match between brush and ring. The rings did not spot any more.—Moral: Use correct brushes and save the matches.

Q. #9. Can we get along with less grades of brushes.
A. It is a well known fact that we have entirely too many grades and variations. Brush makers are doing their best to remedy this defect.

Q. #10. Should a machine oscillate or not.
A. There are advocates on both sides. An oscillating machine shows more uniform surface wear under brushes. Non-oscillating machines operate more satisfactorily under heavy loads. If brush materials permit the latter condition is probably preferable.

Q. #11. Does the nature of marking of commutator disclose where armature winding (including commutator) or brushes, are at fault.
A. It positively does in all cases. However, so little attention has been paid to this end that it is difficult to get enough facts to prove it.

Q. #12. Four different kinds of "cutting" (reduction in diam.) of contact surface under brush.
A. 1. The ordinary wear through abrasive action of brush takes a relatively long time. It manifests itself by the wave-like appearance of surface.
2. The reduction of surface by arcing. This is very destructive and quick acting.
3. The well known tendency of the positive brushes (generator sense) to collect copper, popularly known as "Electrolytic Action." Most prevalent with graphite brushes.
4. The so-called "Threading" of surface by electrographitic brushes which are otherwise non-abrasive. Particles of the brush break off at entering edge; they are held in position by rotation or slide under brush, thus grooving the surface, their natural hardness being perhaps 50 (scleroscope) while the surface is perhaps 10 or 15 (scleroscope) in hardness only. This action has been more pronounced in recent years, when the binder in brushes has been reduced to obtain a structure which will crumble more readily and is known to give better commutation. Change of brush angle may reduce this action. There are electrographitic brushes on the market now, which will not thread.

Q. #13. Why use brushes when you can get along without them?
A. A humorous story is told about an executive of one of the large brush manufacturing companies visiting his biggest branch office and listening to the manager telling a customer (motor manufacturer who inquired regarding a brush application) that the design better be changed to eliminate brushes entirely since they were not reliable enough for the application in question.

Q. #14. What are the differences in action between positive and negative brushes?

A. Since the nature of transfer of current from brush to commutator or vice versa is probably akin to an arc or like phenomena, we find similar results such as:

Negative brushes (generator sense) wear more.

Positive brushes (generator sense) collect copper.

Positive brushes (motor sense) keep rings brighter.

Above actions are the reason for staggering brushes as shown in text.

Q. #15. How is the friction of brushes affected by the load a machine carries?

A. Many of the otherwise peculiar actions of a brush are explained by the fact that a film is formed under brush at light loads. This seems to increase the friction considerably. We always find more "chattering" and "threading" at light loads. As load comes on, this film breaks down and active parts of brush are in direct contact with metal surface, reducing friction. (See Fig. 25 in text).

Q. #16. What causes brushes to swell?

A. The temperature that a brush is subjected to may cause oxidization and other chemical changes which result in expansion of material. Most non-alloy metal brushes have a tendency to expand and are supplied 10 to 15 mils smaller in size by the makers.

Q. #17. When do rotary rings spot?

A. If brushes are so spaced that the positive peak of current wave occurs always when a certain point of ring comes under certain brushes etc., the rings will mark. If starting current on a. c. side is too high—If brushes have too low a copper content—If there are less than four brushes to a ring (density may be normal).

Q. #18. What would make an ideal brush?

A. If the undoubted advantages of the high high grade pure graphite brush could be embodied in the well known graphitized carbons without the faults of the former grade.

Q. #19. What happens to small enclosure just outside of front bearing covering metal brushes and rings of an enclosed slip ring motor.

A. The enclosure seems to become copper coated on inside from the deposit made by metal brushes. It is best to use "copper impregnated" carbons, which do not "dust."

Q. #20. Why brushes heated on a large slip ring motor?

A. The brushes, 16 in number, were of the graphite type, placed single file, in a holder Yoke of cast brass and small cross section. The heavy current was carried by cables into one end of Yoke and only a few brushes near this end carried the bulk of current due to resistance of Yoke. The difficulty was overcome by carrying current into both ends of Yoke.

Q. #21. Do not get peeved when brush manufacturer sends you a data sheet to be filled out.

A. If it is simply a question of physical dimensions, fill out the spaces which should be provided at foot of sheet. If yours is a case of trouble, you should not hesitate to answer even seemingly unimportant questions to enable manufacturer to help you.

Q. #22. What causes the different marking of every 2nd, 3rd or 4th bar of a commutator?

A. If there are 2, 3 or 4 coils for each armature slot and commutator division, the commutation is not the same for each of these coils and the respective bars will take on a different color or one of them may even show burning.

Q. #23. Which are the bad pigtails where pigtail trouble is evident?

A. The good looking pigtails usually are the trouble makers. They carry no current because the resistance at insert end may be very high. That leaves the pigtails with the good connection to carry more current than their share, discoloring and burning them. Replace the "good looking" pigtails.

Q. #24. Why pigtails on graphite brushes give out faster?

A. All natural graphite brushes have a high cross resistance due to the arrangement of the flakes of graphite in layers. The usual riveted shunt makes contact with one layer only. Much heat is generated by the current traveling through the various layers to get to shunt. The brush disintegrates at that point. The solder melts. The shunt fails. Use at least 2 shunts of the cemented type. Arrange these shunts so they make contact with the various strata in the brush.

Q. #25. What a Street Railway Company did when brushes suddenly began to burn, flash and wear down during a prolonged cold spell in winter time.

A. Instructions were given to immediately increase brush tension 25% and further trouble was avoided.

Q. #26. Why should you always use pigtailed brushes?

A. It has become standard practice to use pigtails on medium and large size brushes. Relatively small brushes of ¼ square inch cross section or less are often not provided with pigtails because "they carry only a small current." These small brushes will function far more satisfactorily if pigtails are provided. Take the case of a certain Street Railway Company which used compressor brushes without pigtails at a certain cost per year with many compressor failures. When pigtailed compressor brushes were installed the brush cost per year was cut in half and failures were practically eliminated.

Q. #27. How one large utility system keeps its rotaries in good shape, and why another system cannot do as well.

A. A certain Railway system in one of the large metropolitan centers is fortunate in having a relatively large number of rotaries in each substation. This enables it to keep a fairly constant normal load by cutting machines in and out to suit the demand. Load factor is high. Performance is normal. The temporary application of a few cleaning brushes keeps the few commutators which tend to

discolor in good shape. Another system on similar service has a lesser number of rotaries in each substation. Peak loads per machine are higher, load factor is lower, performance is less satisfactory. Commutators have to be ground more often.

Q. #28. How to run a machine with ½ the normal number of brushes.

A. Since the contact drop of brushes depends on the total pressure on brushes and not on the pressure per square inch it is possible to run a machine with one half the number of brushes, if the spring pressure is increased to double the normal amounts. It is assumed that the original density is not over 35 amps., per square inch approximately and it is recommended that interpoles be adjusted for more compensation. To demonstrate this the Electro Dynamic Company of Bayonne, N. J., tested their standard 50 HP motor at 1710 rpm and removed brushes etc. in accordance with above and tested it again. While the commutation was not as good in the latter case the commutator temperature was reduced by 6° C., nevertheless. It is reasonable to assume that brushes would wear faster under the abnormal condition.

Q. #29. What is perhaps the most common mistake made in handling brushes?

A. Not enough pressure is used to meet all conditions.

Q. #30. What causes the lightning like marks in side of brushes?

A. It has been pretty well demonstrated that these marks are due to foreign particles of grit or dirt which work their way along the surface of brush under the peculiar conditions of vibration existing particularly on moving equipment.

Q. #31. What causes hunting in motors.

A. An overcompensated interpole motor with brushes perhaps slightly back of proper position may, when load is suddenly thrown on at high speed (weak field), cause enough decrease in counter electromotive force of armature (through Interpole, etc. influence) to force a dangerous increase in speed. If now the inertia of load is high the current keeps on rising until interpole is saturated. Then current begins to decrease. This and the high inertia of load may now raise the counter electromotive force above the impressed e.m.f. and armature will act as brake. This same cycle repeats itself. Remedies—cut down compensation of interpole, cut down interpole core, move brushes into correct neutral, put a few stabilizing turns (compound cumulative) on fields.

Q. #32. What causes "side wear" in brushes?

A. When the pigtail of a motor or generator brush breaks off, we find that brush wears away where it is in contact with holder.—Mostly due to carrying of current under adverse conditions of pressure and vibration (see also Q 26). Brushes on ventilated street railway motors are operated with high spring pressure which keeps a brush holder shunt in intimate contact with brush and thus replaces the standard pigtail of the stationary equipment. The "side wear" experienced with these railway brushes has been proved to be largely due to dust taken in with cooling air. (See also Q30). —In latter case take in clean air from top of motor and shield commutator.

Q. #33. Brush temperature vs. commutator temperature.

A. Brushes according to their composition and manufacturing process may be subjected to considerable heat. As long as they function properly there should be no objection. The resultant commutator temperature is important and should in no case exceed the limits set by specifications.

Q. #34. What is temperature at contact face of brush?

A. Careful research has shown that the points of contact face on brush which carry the current have a temperature of 1200°C to 1500°C.

Q. #35. Should commutators be "slotted" or left "flush mica"?

A. The advantage of "slotted mica" commutators is now universally understood. Most machines are now "undercut". Where crane motors (or other equipment) are apt to gather oil on commutator it is safer to leave them flush. This may also apply to cases where moisture is excessive (steam condensation). Low voltage machines using metal graphite brushes, especially of the high metal type, are considered safer with flush commutators.

Q. #36. Do fumes, gases, dust, etc. have any influence on brush performance?

A. Many cases of chemical action of gases are on record either through adverse influence on commutator surface or decomposition of brush or pigtails. Dust often causes wear and ridging of rings.—Remove causes.

Q. #37. Is there any methods to relieve selective action of brushes during operation when heavy currents are involved such as occur in large lighting rotary rings for instance?

A. When extreme selective action of brushes is evident (heating, burning, vibration of pigtails) reduce the load for a minute or more. Often the selective action disappears in bringing up load, particularly on rotary ring brushes. This is a handy remedy where enough rotaries run in parallel (large Edison systems etc.) and load may be carried temporarily on other units. (Unfortunately method is not possible in turbine or synchronous motor rings on account of the nature of load carried by brushes).

QUESTIONNAIRE

FOR

THE IRON AND STEEL INDUSTRY

COVERING

ARC WELDING EQUIPMENT, AUTOMATIC ARC WELDING, ELECTRODES, OPERATORS, CARBON ARC WELDING, RESISTANCE WELDING, ATOMIC HYDROGEN WELDING, ACETYLENE WELDING, THERMIT WELDING AND GENERAL QUESTIONS

BY

WELDING ENGINEERING DIVISION

OF

THE ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS

ARC WELDING EQUIPMENT

1. How many arc welder motor generator sets do you have?
2. How many single operator arc welding sets?
3. How many multiple operator arc welding sets (more than one operator welding from one machine)?
4. What is the total welding current capacity (amperes) of these machines?
   (a) Single operator sets.
   (b) Multiple operator sets.
5. Are generators constant voltage or variable voltage? How many of each?
6. Under what conditions do you favor single or multiple operator welding sets?
7. Do you favor constant voltage or variable voltage $\left\{\begin{matrix}\text{constant energy}\\ \text{constant current}\end{matrix}\right\}$ generator.
8. Is your arc welding—Production?
   Maintenance?
9. What trouble do you have with your electrode holders?
10. How many A. C. arc welders do you use?
    Have you a preference between A. C. and D. C. arc welders?
    Do the operators themselves have a preference and why?
11. Is the metal deposited with the A. C. as good as with the D. C. welders?
    If not, wherein does it vary?
    Can you use the same electrode with A. C. as with D. C.?
    If so, what type do you use?
12. With a given size of electrode and a given value of welding current, will the A. C. welder deposit as much metal as the D. C.?
    If not, what is the proportion?
13. Have you made tension, torsion and shear tests of welds made with A. C. welder and D. C. welder?
    If so, was there any marked advantage in tests in favor of either A. C. or D. C.?
14. Are your A. C. welders equipped with high frequency for starting the arc?
15. How many different manufacturers' machines do you have?
16. If you were buying a new welder, what would be your general specifications?
17. Do you use the arc for cutting? Why?
18. Are A. C. and D. C. both satisfactory for cutting?

AUTOMATIC ARC WELDING

1. Do you use automatic metal arc welding?
2. Do you use bare or coated electrodes?
3. What difficulties have you encountered in any of the following automatic arc welding problems?
   (a) Inherent characteristics of machine.
   (b) Buckling of material being welded.
   (c) Penetration.
   (d) Breaking after welding.
   (e) Machining weld.
   (f) Consistency of results.
   (g) Of what does your welding consist.
4. Do you use automatic carbon arc welding?
5. What difficulties have you encountered in any of the following automatic carbon arc welding problems?
   (a) Inherent characteristics of machine.
   (b) Buckling of material being welded.
   (c) Penetration.
   (d) Breaking after welding.
   (e) Machining weld.
   (f) Consistency of results.
   (g) Of what does your welding consist?
6. Do you use single or double arc?

ELECTRODES

1. What sizes and types are mostly used?
2. Do you use heavily coated, bare or lightly coated electrodes?
3. Do you find any marked advantage with heavily coated electrode, taking into consideration (cost per pound of deposited metal, strength of deposited metal, speed of welding, ductility and soundness)?
4. What percentage of loss do you have due to short ends in welding electrodes?
5. What length of electrode do you use?
6. What grade of electrode do you use for building up
   (a) Structural material.
   (b) Rolls.
   (c) Steel Castings.
   (d) Gears.
   (e) Pinions.
   (f) Shafts.
   (g) Wobblers.

7. What electrode do you use on
   (a) Boilers.
   (b) Stoker Links.
   (c) Cast Iron.
8. Do you have a table with current values, size and type of electrodes for each application or do you depend on operator's judgment?

OPERATORS

1. Do you have a welding supervisor?
2. Do you have a school for your welding operators?
3. Do you have your operators pass a qualification test?
4. Should operators all be qualified on horizontal, vertical and overhead welding?
5. What basis of comparison do you use in classifying operators?
   (a) Pounds per hour.
   (b) Feet per hour of various size fillets.
6. Do you make periodical tests of your welding operators?
7. What tests do you make?
   (a) If a tensile test is required, what are the requirements?
   (b) What is your method of inspection and test measurements of fillet welds?
   (c) Are fillet gauges used.
8. How do you classify your welders in comparison to other crafts?
   (a) Skill.
   (b) Semi-skilled.
9. What percentage of labor turnover do you have among your operators per year?
10. Do you use and what results are obtained from various incentive systems of compensation as applied to various types of welding?
11. Are the operators responsible for maintenance of machines and equipment?
    (a) If not, who is responsible?
12. Are your arc welder operators also acetylene welders?

CARBON ARC WELDERS

1. To what extent do you employ carbon arc welding?
2. Do you experience any porosity of the welds or lack of consistency?
3. Do you experience any difficulty with carbon in the weld metal?
4. Do you use a fill-in rod of same chemical composition as base metal?
5. What is the minimum thickness, maximum thickness of material you are able to weld with the carbon arc?

RESISTANCE WELDING

1. What is the total K.V.A. of all resistance welders in your plant?
2. Do you find it necessary to install voltage regulators on large resistance welder units?
3. Do you find it necessary to use motor-generator sets (three phase motor—single phase generator) to furnish power to your resistance welders:
   (a) For power factor correction.
   (b) To balance single phase on multiple phase line.
   (c) To prevent power surges on shop line.
4. Do you find it necessary to use synchronous condensers or static condensers for power factor correction?
   (a) Which do you use?
   (b) Are they on the primary (6600-4400-2200) or secondary (550-440-220) side of the transformer?
5. Are you paying a penalty for low power factor caused by resistance welder load?
6. Do you notice any fluctuation of voltage at generating station or main sub-station caused by welder load?
7. Do you find your resistance welders cause any more surges on your lines than large motors driving shears, punch presses or rolls, etc.?
8. Do you find a resistance welder causes as much disturbance as a large motor in starting?
9. When more than one resistance welder is on a given line, do you experience more fluctuation than a single welder?
10. If you are penalized for your welder load, what is the percentage of penalty?
11. Are your welders full automatic as to current control?
12. Do you do seam welding?
13. What is the maximum thickness of plates? Minimum thickness?
14. What is the method of current control you use?
15. What speed per minute do you obtain?
16. Have you tried the thyratron type control for seam welding or spot welding?
17. What success?
18. In spot welding is your current control automatically controlled?
19. In your opinion is resistance welding more reliable and stronger than arc welding?
20. If so, for what types of joints and what applications?

ATOMIC HYDROGEN WELDING

1. Do you use the atomic hydrogen method of welding?
2. What class of work do you apply it to?
3. Do you use hydrogen or dissociated anhydrous ammonia?
4. What is the minimum, maximum thickness of material you weld with the atomic hydrogen welder?
5. What success have you had with this welder in repairing machine tools and cutters?
6. Have you found it best adapted to production or repairs of equipment?

ACETYLENE WELDING

1. Do you use acetylene welding for maintenance —production?
2. Do you generate the acetylene?
   (a) Purchase acetylene tanks?

3. What is the minimum thickness, maximum thickness of the material you weld with when using acetylene welders?
4. What are your costs in percentages to arc welding?
5. Do you maintain a school for training your acetylene welders?
6. In welding cast iron, what welding filler rod do you find best?

THERMIT WELDING

1. Do you use thermit welding for maintenance?
2. For what class of work do you use thermit welding?
3. Do you have a special thermit welder, or can your electric welder do both?
4. What success do you have on heavy repairs?

GENERAL

1. Do you depend upon your ammeter for your current settings or do the operators depend upon their judgment?
2. How many meters on your machines are in working order?
3. Do you find the volt-meters, ammeters, etc., the manufacturer puts on his welders a benefit?
4. Are your single operator sets mounted on trucks?
5. How many times are they moved in a month?
6. Is the design of your trucks such that they are likely to upset during transportation?
7. Do you have any complaints of your welders causing radio interference?
8. Do you favor polarity reversing switches?
9. What troubles do you experience with cables?
10. What type or grade of cable do you prefer?
11. Have you standardized on ground clamps? If so, what type or grade?

THE

STATISTICAL DEPARTMENT

OF THE

IRON AND STEEL ENGINEER

will assist you

in

1. Research and development.
2. Sales.
3. Apportioning developing costs.
4. Potential markets.
5. Determining renewals to be purchased.
6. Regional possibilities.
7. Steel mill centers to be modernized.
8. Plant names and locations.
9. Percentage of plants modernized.
10. Percentage of plants to be modernized.
11. Lubrication equipment analysis.
12. Combustion equipment analysis.
13. Electrical equipment analysis.
14. Mechanical equipment analysis.
15. Useful to mill builders.
16. Useful to bearing manufacturers.
17. Useful to gear builders.
18. Useful to furnace builders.
19. Useful to electrical manufacturers.
20. Useful to builders of combustion equipment.
21. Useful to builders of lubrication and device manufacturers.
22. Useful to crane builders.
23. Useful to manufacturers supplying equipment for coke ovens.
24. Useful to manufacturers supplying blast furnace equipment.
25. Useful to manufacturers supplying equipment for open hearths.
26. Useful to manufacturers supplying equipment for Bessemer converting plants.
27. Useful to manufacturers supplying equipment for all classes of rolling mills.
28. Useful to manufacturers supplying equipment for power houses.

THE ABOVE INFORMATION SUPPLIED GRATIS TO ADVERTISING CLIENTS.

Write for further particulars.

IRON AND STEEL ENGINEER

1010 EMPIRE BUILDING, PITTSBURGH, PA.

A. I. & S. E. E.—TWENTY-FIVE YEARS OF ENGINEERING SERVICE TO THE IRON & STEEL INDUSTRY

ITEMS OF INTEREST

PERSONNEL CHANGES

▲

Walter H. Burr, formerly Electrical Superintendent of the Lukens Steel Company at Coatesville, Pa., has been promoted to the Superintendency of both the Electrical and Mechanical departments of that company. Mr. Burr is a very active member of the A. I. & S. E. E. At the present time he is serving as second Vice President, also Chairman of the Electrical Developments Committee of the Society. The Association wishes at this time to congratulate Mr. Burr on his advancement and wishes him continued success in his new capacity.

W. H. BURR

▲

Ralph Kelly, formerly southwestern district manager at St. Louis for the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., has been named central district manager with headquarters at East Pittsburgh. He has been with the company since 1909, and has been in the St. Louis office since 1926. John Andrews, Jr., continues as Pittsburgh sales manager.

▲

F. E. Chesney has been appointed purchasing agent of the American Steel & Wire Co., with offices in the Rockefeller Building, Cleveland, succeeding J. N. Fleming, who retired Dec. 1 after 46 years continuous service. Mr. Chesney was for a long time connected with the company's purchasing department in Chicago and was transferred to Cleveland more than a year ago as assistant purchasing agent. D. C. MacDonald remains as assistant purchasing agent, with office at 94 Grove street, Worcester, Mass.

▲

Charles F. Blackmer, vice president in charge of operations of the American Steel & Wire Co., Cleveland, becomes president of the company Jan. 1, in succession to John S. Keefe, president since Dec. 28, 1927.

Mr. Keefe, who is rapidly approaching the compulsory retirement age of the United States Steel Corp., of which the American company is a subsidiary, has been identified with the Corporation or a component company since 1888.

Mr. Blackmer was born in Worcester, Mass., April 1, 1879. In 1898 he became assistant in the laboratory at Waukegan, Ill., of the Washburn & Moen Wire Co. When in 1899 the Washburn & Moen company was acquired by the American company, Mr. Blackmer was a foreman in the wire-drawing department of the Waukegan plant.

In March, 1912, he was made assistant superintendent of the Waukegan Works. The Minnesota Steel Co. being projected by the Steel corporation, he was assigned to Duluth to design and put into operation the wire mills there, being made superintendent in June, 1921. The Minnesota company is now being managed by the American company.

Managership of the Pittsburgh district of the American company was tendered to him in March, 1925. In that capacity he served until December, 1927, when he was made general superintendent of all the company's mills, with headquarters at Cleveland. In April, 1930, he was made a vice president in charge of operations, a post which he filled until his succession to the presidency of the company.

▲

Mr. T. E. Hughes, formerly assistant Superintendent and more recently acting Superintendent of the Electrical Department of the Carnegie Steel Company at Duquesne, Pa. has been appointed as the head of the Mechanical and Maintenance Departments. Mr. Hughes has been an active member of the A. I. & S. E. E. for many years. He has contributed many valuable discussions to the editorial columns of the Iron and Steel Engineer, chiefly, those dealing with the Safe Practices in Connection

T. E. HUGHES

with the Operation of High Tension Power. The Association wishes at this time to congratulate Mr. Hughes on his advancement and wishes him continued success in his new capacity.

▲

Mr. W. B. Shirk, former steel mill engineer of the Westinghouse Electric & Mfg. Company at East

W. B. SHIRK

Pittsburgh, has accepted a position with the Gulf Refining Company of Pittsburgh, Pa., in the Lubrication Sales Department. Mr. Shirk has been an associate member of the A. I. & S. E. E. for twelve years and has taken a very active part in all of the Association activities. He has presented many papers before the various district sections of the Society and at the last convention, in Pittsburgh, Pa., delivered papers before the Electrical and the Lubrication Engineering Divisions of the Association.

▲

C. M. Konkle, of the Federal Shipbuilding & Dry Dock Co., Kearny, N. J., has been named auditor of the Tennessee Coal, Iron & Railroad Co., Birmingham, Ala., succeeding F. B. Winslow, resigned.

▲

Walter F. Perkins, general manager, Harrison, N. J., works of the Worthington Pump & Machinery Corpn., has resigned to become vice president and general manager of the Bartlett-Hayward Co., Baltimore. Mr. Perkins was associated with the Bartlett-Hayward Co. from 1914 to 1927, when he became connected with the Worthington company.

Hugh Benet, formerly manager at the Holyoke, Mass., works, has been made works manager at the Harrison plant of the Worthington company.

▲

H. J. Davis, who has been general superintendent of the Clairton, Pa., works of the Carnegie Steel Co. since 1905, has submitted his resignation effective Dec. 31. Mr. Davis has been identified with the Steel Corporation subsidiaries and their predecessors for 43 years, having begun work as a machinist in the Edgar Thomson works, Braddock, Pa., in 1889. He later served as master mechanic at the Homestead steel works, and subsequently became general superintendent of the Donora, Pa., works, American Steel & Wire Co. From this position he went to Clairton in 1905.

▲

Douglass Millard, manager of fuel sales of the Colorado Fuel & Iron Co., Denver and Pueblo, Colo., has been appointed manager of by-product sales of the company, by Arthur Roeder, president.

▲

Farrel-Birmingham Company, Inc., Ansonia, Conn., announces the appointment of Richard A. North as Assistant Chief Engineer.

To his new post Mr. North brings a diversified experience in various phases of mechanical engineering and industrial management acquired in several years of collegiate teaching and in connections with prominent firms in the manufacturing and transportation fields.

▲

WITH THE MANUFACTURERS

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NEW ALL-STEEL SILENT GEARS

Interest is being displayed in the new silent all-steel gears and gear blanks being manufactured by the John Waldron Corporation of New Brunswick, N. J.

A new bulletin has just been released to completely describe the patented construction and combined advantages of these new silent all-steel gears. It contains complete tables of sizes, illustrations and cutting instructions. A copy may be had by writing to either the manufacturer or to Smith & Serrell, General Sales Agents, Globe Indemnity Building, Newark, N. J.

▲

IMMERSION HEATER

An immersion heater designed to warm oil, water or other liquids quickly, is being manufactured by The Martindale Electric Company, Cleveland, Ohio. The heater is made in two styles, one without thermostatic control with a rating of 800 watts and the other with a built-in thermostatic control with a rating of 525 watts. The heaters are made for use on 110 volts only. The thermostat used is designed to control the range from room temperature to 300 deg. F. The heaters are 30 in. in length, having a minimum immersion depth of 9 in. and a maximum depth of 25 in.

▲

OILPROOF OKOCORD

In certain types of service portable cords are subjected to the continual attack of oil resulting in deterioration not only of the outer coverings but eventually of the insulation. To meet this condition The Okonite Company of Passaic, New Jersey, has developed a full line of portable cords and cables having a special outer sheath which is impervious to the destructive action of oil or grease. This line of cords and cables is called "Oilproof Okocord".

As the name implies, Oilproof Okocord possesses all the good qualities of the Okocord line plus continued resistance to oil, thus rendering it highly suitable for use around machine shops, garages, refineries, oil wells, etc. Strong sunlight and ozone also has little effect on this cord.

NEW MOTOR CONTROL FOR MINE DUTY

A new, across-the-line type, automatic, D.C. Motor Controller has been announced by Cutler-Hammer, Inc., Milwaukee, Wis. It employs a simple, novel, adjustable means of timing to allow the field current of the motor to build up full strength before the circuit to the armature is closed. This feature protects and saves the motor by cutting down the current inrush about 50%.

▲

OZONATOR

The Jefferson Electric Company, Bellwood, Illinois, has just published a four-page illustrated folder describing the Jefferson Ozonator which has recently been put on the market. As the folder indicates, this device has an unusually wide application for purifying and vitalizing air. Write Jefferson Electric Co., Bellwood, Ill., for a copy.

▲

MOTOR REDUCTION UNIT

Allis-Chalmers Manufacturing Company announce the development of a Motor Reduction Unit for use where low speed drives are required. A standard round frame type motor is mounted directly on the gear reducer housing thus forming a compact unit. Helical gears are used which permits the highest possible efficiency and the most quiet operation.

Standard speeds at the power take-off are from 3.02 R. P. M. to 380 R. P. M., but lower speeds can be provided. 6.08 R. P. M. is obtained with the use of a 1750 R. P. M. motor.

The bearings supporting the gear drives are ball or roller type. Lubrication is automatic and continuous insuring an adequate supply of lubricant at all times. Standard units are arranged for floor mounting. Units can be supplied for wall, ceiling or vertical mounting. Any desired type of motor may be supplied—standard squirrel cage induction motor, wound rotor type, enclosed fan-cooled, explosion proof, or direct current.

Inherent advantages of separate motor and reducer construction are maintained such as ease of maintenance, replacement of individual units, adaptability to change in ratios, etc.

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NEW BULLETINS ON LUBRICANTS

National Carbon Company, Inc., Carbon Sales Division, Cleveland, Ohio, has recently issued three new bulletins covering the application of Gredag Lubricants. These bulletins are known as Catalog Sections G-132, G-232 and G-332. Catalog Section G-132 gives a complete description of all grades of Gredag Lubricants and is a general treatise on lubrication. Catalog Section G-232 applies specifically to the lubrication of outdoor equipment and Catalog Section G-332 covers the lubrication of Industrial Equipment. Copies of these bulletins may be obtained by writing to the company, addressing your inquiries to P. O. Box 400, Cleveland, Ohio.

▲

A NEW COATED ELECTRODE FOR MANGANESE WELDING

A new coated electrode for manganese welding has been announced by the General Electric Company. This new wire finds its principal application in the building up of worn manganese steel castings to original dimensions and in the repair of such fractured parts. It also can be readily applied to obtain a manganese steel surface on parts of ordinary steel and iron, thereby giving the parts a tough, work-hardening, wearing surface at a low cost. Other applications will be found in worn equipment. Considerable saving is possible through reclaiming instead of scrapping, dipper teeth, crusher mandrels, and all pulverizer parts, as well as worn parts of numerous items of equipment used in the oil fields. In addition, this new electrode should be of great interest to the traction industry for building up worn switches, frogs, and crossovers.

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OBITUARIES

Mr. P. M. Smith, Pittsburgh District Manager of the Treadwell Engineering Company, died at his home, Mt. Lebanon, Pa., December 10, after a short illness. Mr. Smith was an associate member of the A. I. & S. E. E. for many years. His host of friends in the Steel Industry together with the members of the Association wishes at this time to extend their condolences to the family and associates of this well known engineer.

▲

George H. Isley, 50, manager of the combustion control department, Morgan Construction Co., Worcester, Mass., died November 30. In 1906 he entered the employ of the Morgan company as a draftsman. For many years he was active in the gas producer department of that company, where he contributed a number of inventions and patents to the development of the producer gas machine. In 1917 Mr. Isley became interested in the improvement of high temperature furnaces and soon centered his attention upon the development of a high-grade reversing valve. Although a complete mechanical and practical success, after making a number of installations, his acute sense for simplicity and directness inspired him with the idea of completely eliminating the reversing valve, so-called, by the Isley system of regenerative furnace arrangement and operation.

▲

Cuyler Adams, 80, who discovered the Cuyuna iron range in Minnesota and built the Cuyuna Iron Range railroad, died Nov. 29, at his winter home at Tryon, N. C.

▲

Elmer E. Stone, 77, general purchasing agent of the American Steel & Wire Co., Cleveland, until his retirement a year ago, died at Cleveland, Nov. 12. For 49 years he was associated with the American Steel & Wire Co., the last 30 as general purchasing agent.

▲

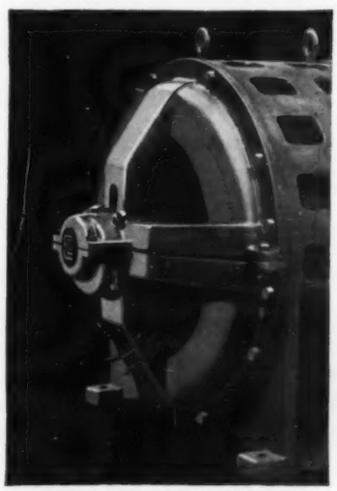
Regis G. Snyder, 25, son of W. T. Snyder, of the National Tube Company, McKeesport, Pa. and a past President of the A. I. & S. E. E., died at his home in McKeesport, Pa., after a short illness. Regis was well known throughout the Pittsburgh Steel district having been associated with different steel mill equipment manufacturers during the last few years. The Association wishes at this time to express their deepest sympathy to the family and friends of Regis.

OUR SHELVES ARE BARE

. . . NOT because we're sold out—not because we have depression-cold feet. Our shelves are bare simply because we don't build motors that way.

Too often, when a motor is sold, it is customary to reach up on the shelf and haul down a general purpose motor of average design. Such a motor usually gives average results, whereas a motor designed for the specific job should fit the requirements like a glove.

ELLIOTT MOTORS



Built to the job

Elliott motors are all tailor-made to the individual job for which they are sold. For each application, design features are manipulated and certain of them emphasized to meet the user's particular requirements, giving him certain decided advantages not to be obtained from a standard design motor.

Since built-to-the-job motors are our specialty, we are set up to turn them out promptly.

Do you want an average design motor, or a motor that will exactly meet your requirements? If you want a motor designed to the job, consult Elliott.

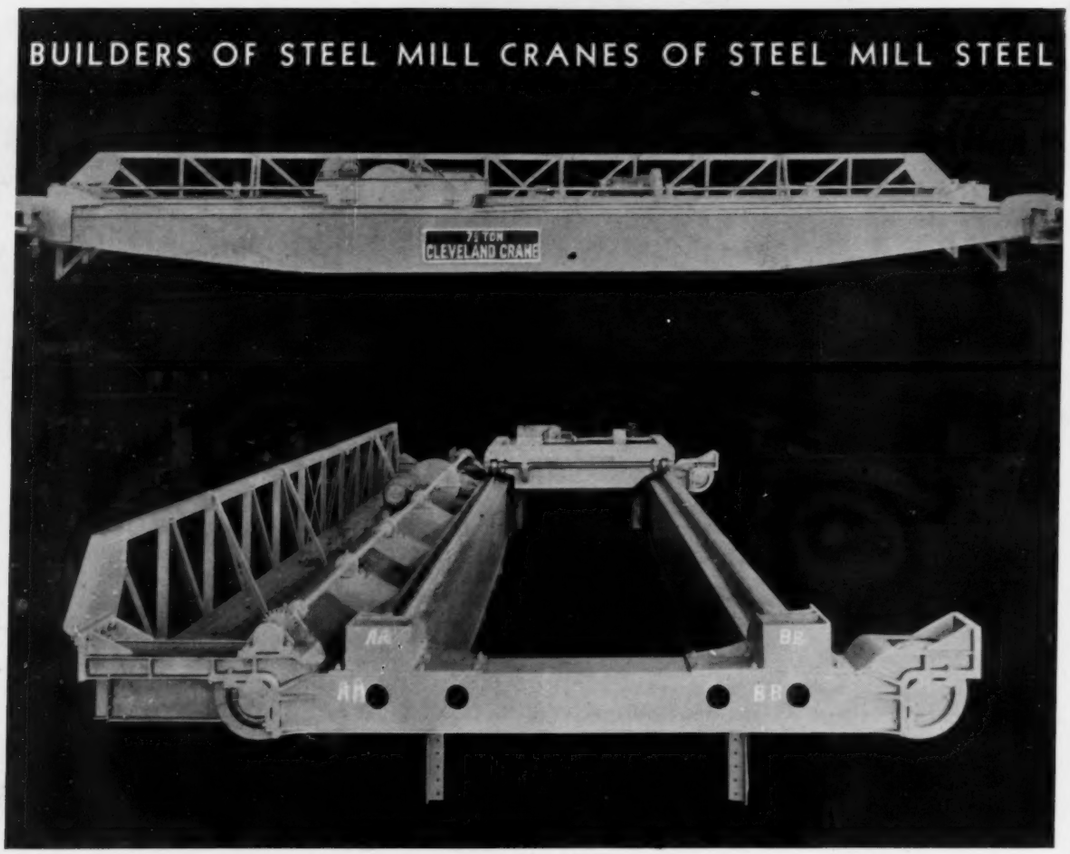
ELLIOTT COMPANY
PITTSBURGH, PA.

Electric Power Department RIDGWAY, PA.

District Offices in Principal Cities

L-680

BUILDERS OF STEEL MILL CRANES OF STEEL MILL STEEL



Cleveland Crane Quality is featured in this crane having welded one-piece rolled steel trolley frame, bridge girders and end trucks - roller bearings throughout - herring bone gears running in oil.

This Quality is reflected in lower operating costs - less maintenance - and uninterrupted materials handling service.

also Builders of CLEVELAND TRAMRAIL MATERIALS HANDLING SYSTEMS

5200 Cranes have been built by Cleveland in 35 years. This well fits us to meet your most exacting modernizing requirements.

THE CLEVELAND CRANE & ENGINEERING CO.

NEW YORK DETROIT WICKLIFFE OHIO PITTSBURG CHICAGO

CLEVELAND CRANES

All Sizes for Every Service

If wiring could shout It's Hot!

IN certain jobs where workers are exposed to high temperatures they are equipped with the protection of asbestos clothing, enabling them to function in comfort and efficiency.

Yet how general it is for engineers to install vital electrical circuits in locations where severe conditions attack the wiring without giving any thought to the protection which these wires *must have* if they are going to stay on the job without failure.

Wherever wiring is located so that it is attacked by heat, fumes, vapors, oil or grease, or where a fire hazard exists, wire should be used which will stand up without failure under these conditions.

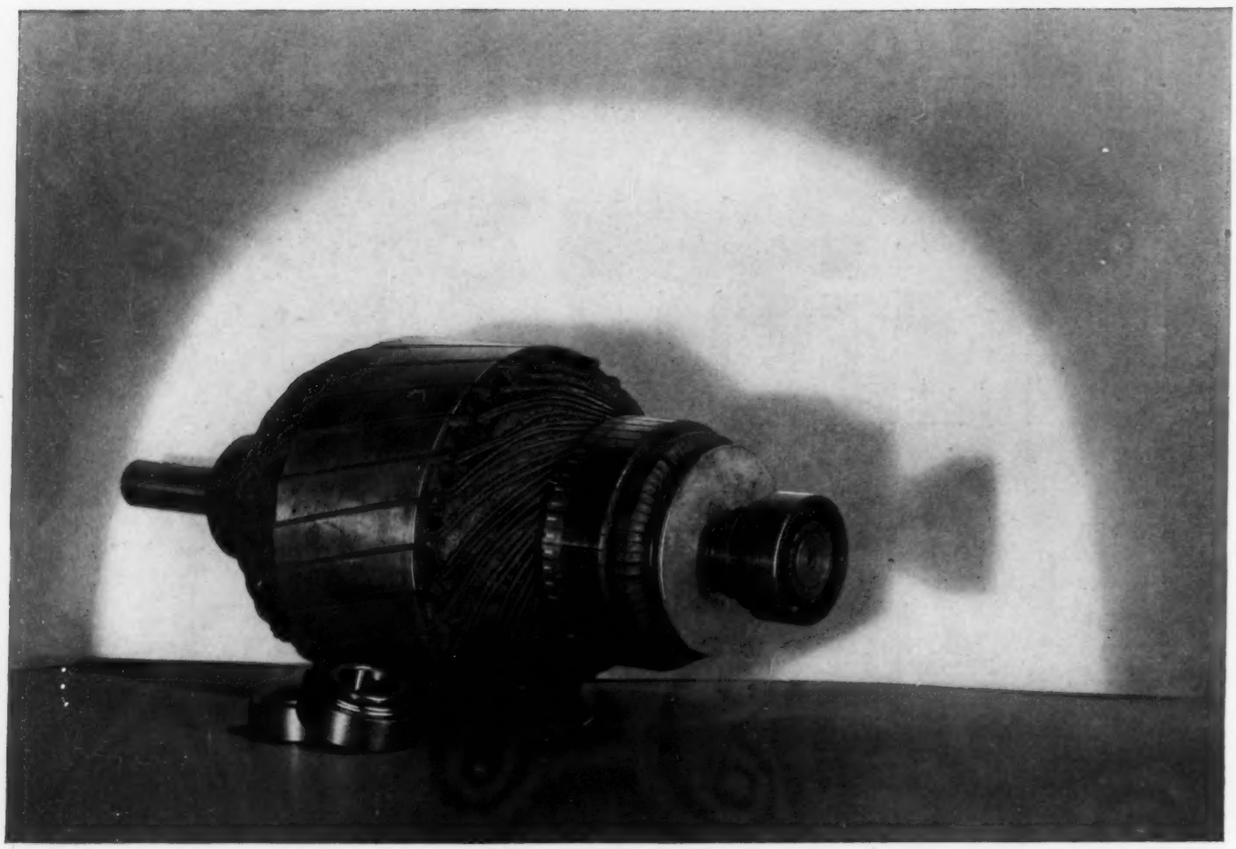
Rockbestos insulated wire is this kind of wire. It can't burn, can't deteriorate from heat, doesn't rot from oil or grease, fumes and vapors can't eat it and time has no aging effect on it. Asbestos, with which these wires are insulated, is immune to these conditions.

In the Rockbestos line are wires for all lighting and power circuits (up to 7,500 volts —2,000,000 C.M.) for motor leads and coil connections, for rheostat wiring, magnet wire for heatproof windings and flexible cord for drop and extension lights—all with failure-free Rockbestos insulation.

A free data book will be sent without obligation to any interested engineer. Address Rockbestos Products Corporation, 473 Nicoll St., New Haven, Conn.

Photo courtesy Johns-Manville

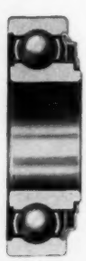
ROCKBESTOS—*the wire with permanent insulation*



4¼ billion revolutions without relubrication

. . . *and still going strong!*

Nearly five years ago, two N-D-Seal ball bearings were installed in a motor to see how long they would operate without lubrication attention. Day and night, for over 40,000 hours, this motor has been driving a testing device in New Departure's laboratory . . . the equivalent of 16 years' normal service . . . and is still going strong! Not a bit of grease has been added since the start, at which time they were charged with the same amount that every N-D-Seal is given before delivery to the customer. New Departure does not advocate negligence like this on the part of N-D-Seal users, but you men who build or buy machinery must see in this test the beginning of a new era in maintenance economy. Every time a man in your shop squirts oil in a hole, he points at a position that should be occupied by a New Departure Ball Bearing in the next machine you buy. Specify New Departures and watch your maintenance costs go down. New Departure Mfg. Co., Bristol, Conn.



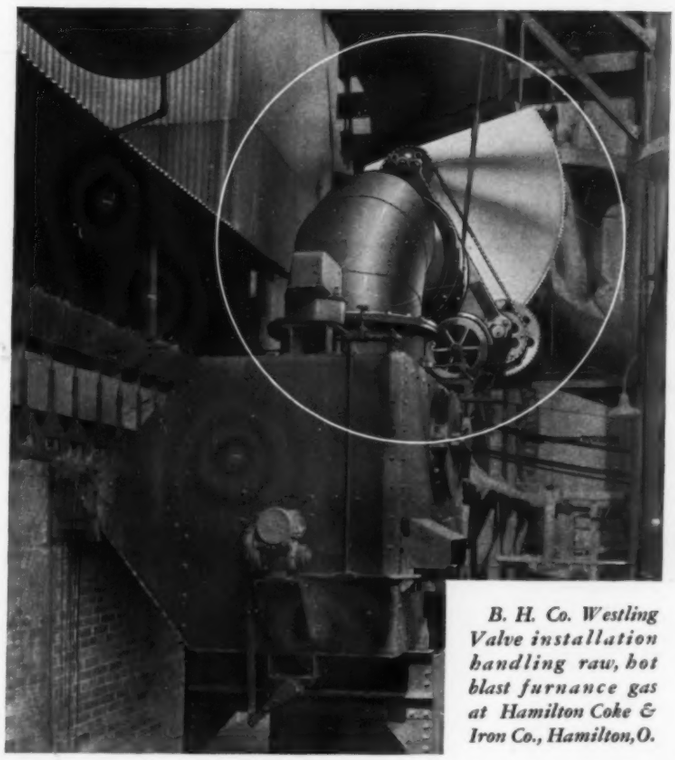
Sectional view N-D-Seal Bearing

NEW DEPARTURE

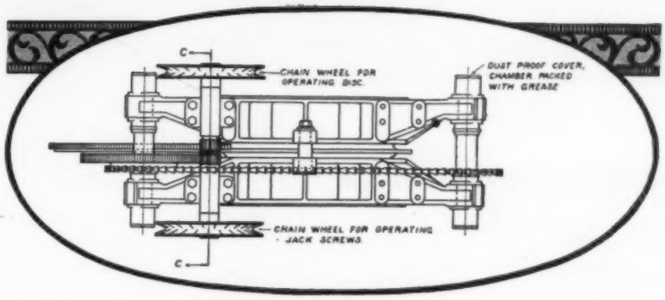
BALL BEARINGS

A. I. & S. E. E. — TWENTY-FIVE YEARS OF ENGINEERING SERVICE TO THE IRON & STEEL INDUSTRY

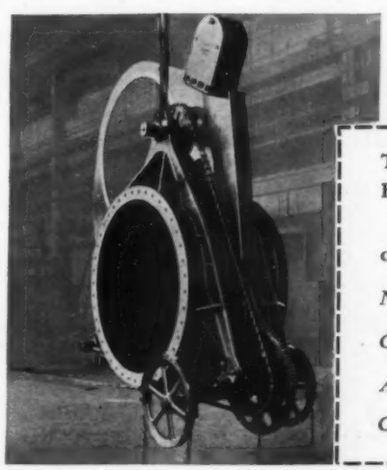
Danger Banished . .



B. H. Co. Westling Valve installation handling raw, hot blast furnance gas at Hamilton Coke & Iron Co., Hamilton, O.



Simplicity of Operating Details is Clearly Shown By the Diagram.



B. H. Co. Westling Valves are made in all standard sizes. Their full opening feature allows for an unobstructed gas flow and the elimination of any deposits due to constriction of pipe area.

The Bartlett Hayward Co. Westling Valve's Speed, Strength, Simplicity and Tightness Assure Efficient Operation — Perfect Safety

Consider these facts about the Bartlett Hayward Co. Westling Valve:

1. ITS STRENGTH: A heavy, annealed, cast steel frame provides a rigidity and structural strength capable of compensating for the maximum operating strains developed.

2. ITS SPEED: The complete operation from open to closed or from closed to open can be accomplished in a minimum of time. For example, a 36" valve can be closed in 42 seconds, and a 60" valve in 1¼ minutes. Both of these times are based on one man operation. This exceptional speed has been the prime factor in the selection of the B. H. Co. Westling Valve for many indoor installations, where speed is of great importance as a safety factor.

3. ITS TIGHTNESS: Another important safety factor—tightness—is well cared for in the B. H. Co. Westling Valve. Careful machining of the bearing surface on the plate assures 100% tightness of the valve in open or close position. Each valve is shop tested for this factor before installation.

4. CONVENIENCE OF OPERATION: It only takes one man to operate a B.H.Co. Westling Valve, through its easy manual control. Another point of convenience—B. H. Co. Westling Valves are assembled and tested in the shop. No extra work necessary at the point of installation.

5. PERMANENCE: B. H. Co. Westling Valves last indefinitely, and work efficiently after long periods of disuse. The only working parts are three chrome steel jack screws, encased in a grease chamber supplied with high pressure lubrication, and permanently out of contact with air, dirt, or gas. If the valve remains in one position for long periods, this arrangement immediately responds to the control when needed.

6. STANDS UP UNDER ALL CONDITIONS: Installations on hot, dirty gases from both producers and blast furnaces, ranging in temperature from 300°F to 600°F have given complete satisfaction. Units can be furnished to withstand any temperature or corrosive conditions in process or plant operations.

7. SAFETY: Add up the factors listed above, and you get safety from the B. H. Co. Westling Valve: 100% safety.

Mail the coupon below for complete specifications, and descriptive literature.

BARTLETT HAYWARD COMPANY

WESTLING VALVE

THE BARTLETT HAYWARD COMPANY
BALTIMORE, MARYLAND

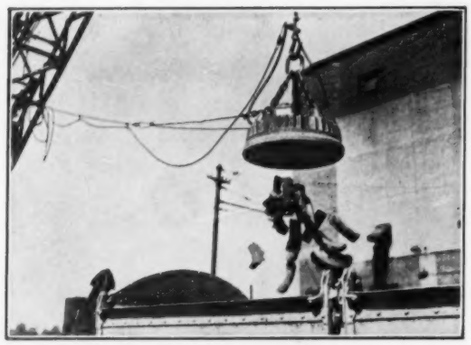
Send me full descriptive literature and specifications of your Westling Valve.

Name.....

Company.....

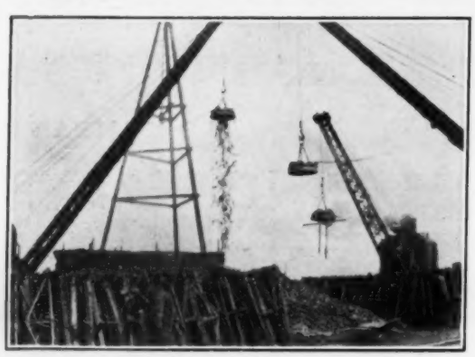
Address.....

City.....*State*.....



Automatically-Discharged

Don't Penalize your Lifting Magnets with Inefficient Control Devices



Manually-Operated Release

NOTE how the EC&M Automatic-Discharge Controller is a time and money saver for every magnet user.

This Controller has only two positions, "Lift" and "Drop". To release a load, the operator merely throws the small Master Switch to the "Drop" position and the load is *automatically* released and the magnet *automatically* disconnected from the line.

Contrast this with previous types of Control Devices which required that the operator had to move his Master Switch from the "Lift" through the "Off" to the "Drop" position and, as the load was released, return the Master to the "Off" position. This required careful attention by the operator to secure a clean release.

Why sacrifice the speed of your crane and magnet? Reduce your handling costs with the greatly improved EC&M Automatic-Discharge Magnet Controller. Your maintenance costs, also, will be reduced, because this controller eliminates the highly destructive arcing on the main contacts. Send today for Specification Sheet S-33 completely describing how this improved controller can be easily applied to magnets of all sizes and types.

THE ELECTRIC CONTROLLER & MFG. CO.
CLEVELAND, OHIO

EC&M AUTOMATIC-DISCHARGE LIFTING MAGNET CONTROLLER

A. I. & S. E. E. — TWENTY-FIVE YEARS OF ENGINEERING SERVICE TO THE IRON & STEEL INDUSTRY

SCHLOEMANN

"MOTOR-ROLLER"

(SCHULTE AND OTHER PATENTS)

Over 5000 of our self-contained Motor-Rollers operating in continuous and reversing service for years in all kinds of mills have proved reliable and instrumental in achieving reductions of operating and maintenance cost.

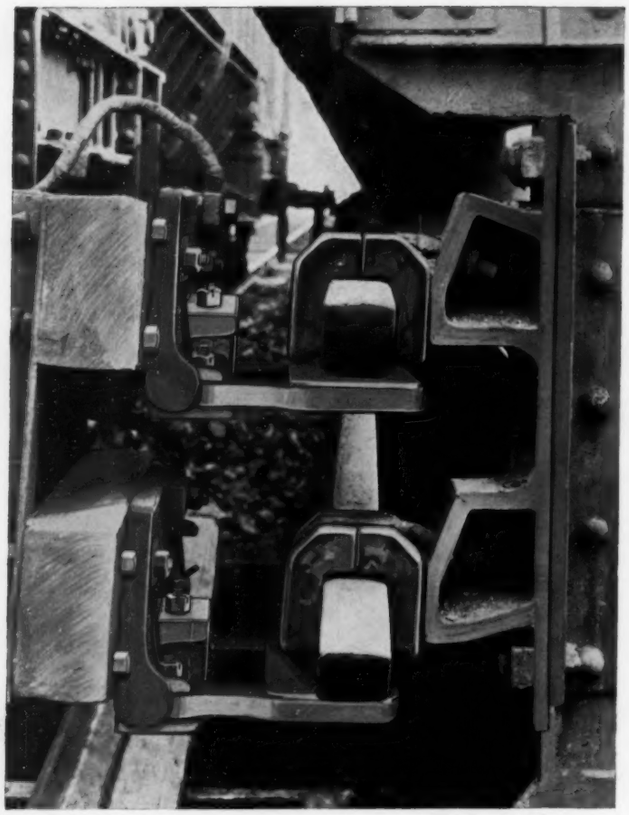
Whether you contemplate the installation of new roller tables, desire to eliminate delays in your mills, or reduce operating and maintenance expense of existing tables, it will pay you to investigate "Motor-Rollers" and to obtain our recommendation.

We invite your request for further information or the visit of one of our Engineers.

SCHLOEMANN ENGINEERING COMPANY
1201 EMPIRE BUILDING PITTSBURGH PA

ROLLING MILL MACHINERY

A. I. & S. E. E. — TWENTY-FIVE YEARS OF ENGINEERING SERVICE TO THE IRON & STEEL INDUSTRY



Keystone Contact Rail Material

Up goes the load! Down goes the load! Always under perfect control of the operator—because Keystone Contact Rail Material provides the constant contact that means, safe, steady transmission of power to your cranes, conveyors and other electric hoisting and hauling systems.

Our engineers will be glad to co-operate with you at any time in the selection and installation of various types to meet your specific requirements.

Refer to our Catalog No. 10 for complete listing.

A Keystone double tee rail standard complete with insulators. Catalog describes many other methods of transmitting power.

ELECTRIC SERVICE SUPPLIES CO.

Home office and plant at 17th and Cambria Sts., PHILADELPHIA; District Offices at 111 N. Canal St., CHICAGO; 50 Church St., NEW YORK.

MANUFACTURERS

of Power and Industrial Equipment

Branches—Investment Bldg., Pittsburgh; 88 Broad St., Boston; General Motors Bldg., Detroit; Canadian Agents, Lyman Tube and Supply Company, Ltd., Montreal, Toronto, Vancouver, Winnipeg.

Just a matter of . . .

"Team Work"

The generators in steel mills must team with motors on rolls, machines and cranes to keep a satisfactory tonnage continuously flowing. They have to take heavy, sudden overloads, handle wide and rapid current fluctuation without fuss or fireworks on commutators. They must do this year in and year out with absolute reliabilty. Crocker-Wheeler Motor Generator Sets have won an enviable reputation by their ability to team up with steel mill equipment, stand up under the severe service and at the same time give high efficiency over a wide range of loads.

Write our nearest district office for further information.

Crocker-Wheeler Electric Mfg. Co.
AMPERE, NEW JERSEY

CROCKER WHEELER

Birmingham Boston Buffalo Chicago Cincinnati Cleveland Detroit
Houston Los Angeles New York Philadelphia Pittsburgh San Francisco Seattle

A suit of clothes is no better than its cloth.

A gear or crane wheel is no better than its hardening

That's why "Tool Steel" gears and wheels are the recognized standard of quality

The Tool Steel Gear & Pinion Co.

Cincinnati, O.

DEFINITE CONTROL OF QUALITY

You are not so much interested in how bearings are made as you are in how they perform. But since dependable bearing operation is predicated on how well they are designed and built, we repeat, that more definite control of quality than in the manufacture of Hyatt Roller Bearings cannot be found. Hyatt Roller Bearing Company, Newark, Detroit, Chicago, Pittsburgh, Oakland.

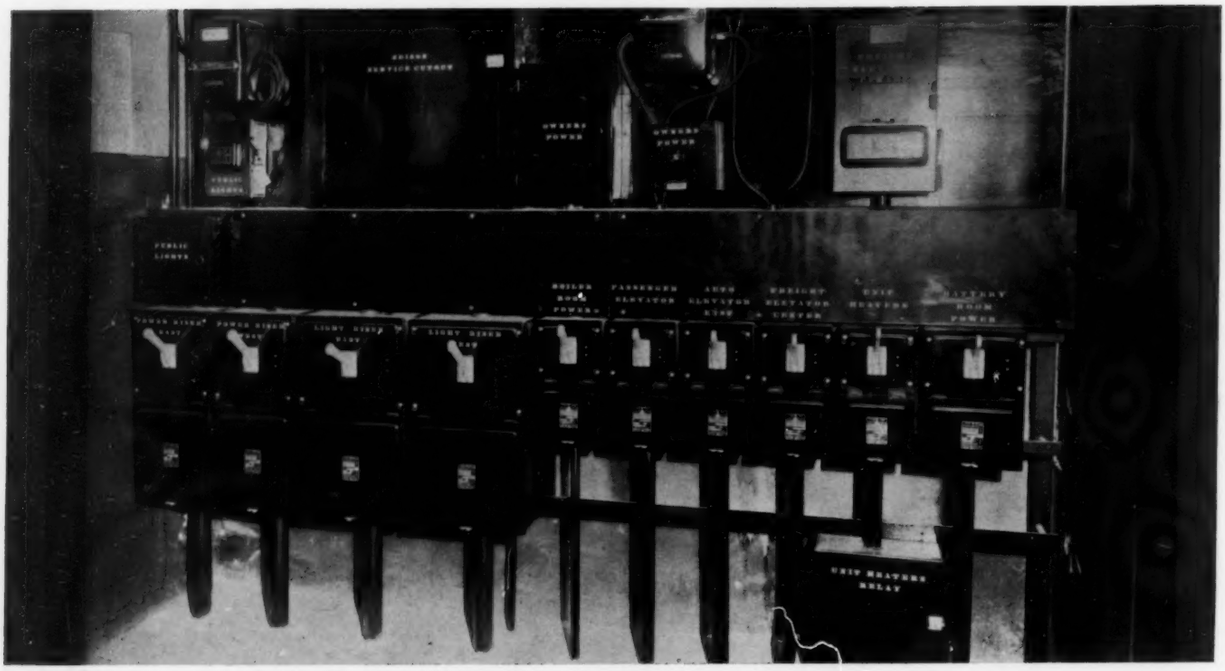
Illustrated — *Hyatt Single Row Radial Bearing and one of our optometer gauging instruments used for accurate final testing on Hyatt solid rollers*

HYATT

ROLLER BEARINGS

PRODUCT OF GENERAL MOTORS

"R. B." SWITCHES CHOSEN FOR VARIED CONTROL



4-200 amp., 6-60 amp. front operated fusible "R.B." switches and 2 meter service switches comprise this distribution center in a modern building.

Distribution board space is reduced by using front operated switches. In the illustration 10 switches . . . 4-200 amp. and 6-60 amp. are installed side by side in a space 9 feet 10 inches wide . . . less than a foot per switch average.

200 amp. circuits
Power riser east.
Power riser west.
Light riser east.
Light riser west.

60 amp. circuits
Boiler room power.
Passenger elevator.
Auto elevator.
Freight elevator.
Unit heaters.
Battery room power.

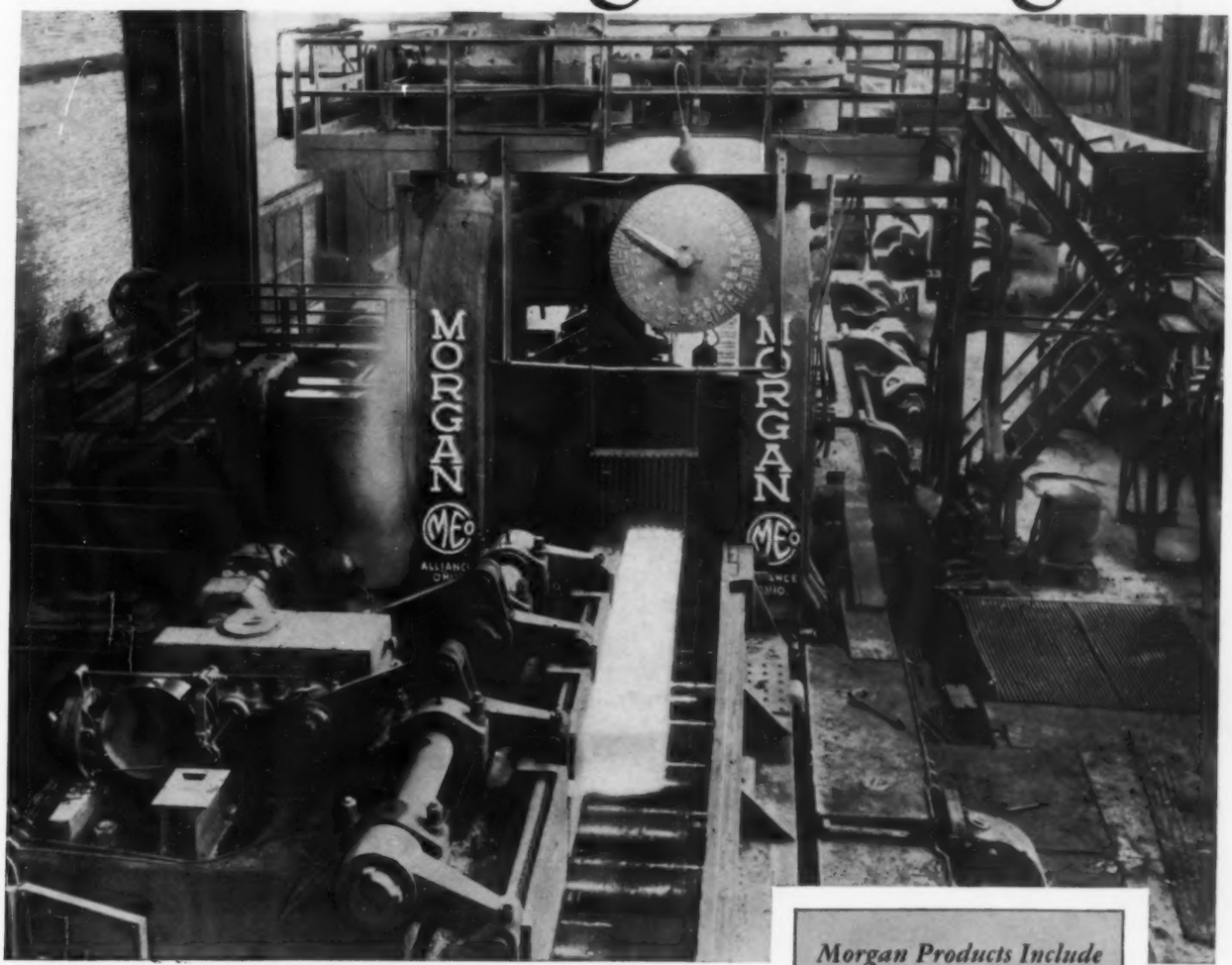
"R.B" switch features
Break full rated load.
"Vystipe" fuse clamps.
Lower half of cover interlocked with switch handle. Lift in "off" position to renew fuses.
Hole in end of handle for stick operation. Handle lies close to cover in "on" and "off" positions.
Slots in handle guard for locking switch in "on" or "off" position.

THE TRUMBULL ELECTRIC MFG. COMPANY

Plainville Conn.

A GENERAL ELECTRIC ORGANIZATION

BUILT BY MORGAN *Engineering* » »



THIS 54″ Blooming Mill is typical of Morgan engineering experience and representative of Morgan shop organization standards of efficiency. It is one of the largest Blooming Mills ever built. Mill housings are one-piece steel castings, insuring rigidity. A two-cylinder roll balance allows for minimum head room. Manipulator is one of the overhead type, compact and accessible. Finger lifts and side guards, each operated by two motors in series, assure quick acceleration and greater tonnage. All outstanding advantages of Morgan design-to-production responsibility are apparent in every Morgan job.

Morgan Products Include

BLOOMING MILLS
PLATE MILLS
CONTINUOUS MILLS
STRUCTURAL MILLS
ELECTRIC TRAVELING CRANES
CHARGING MACHINES
INGOT STRIPPING MACHINES
LADLE CRANES
SOAKING PIT CRANES
STEAM HAMMERS
STEAM HYDRAULIC FORGING PRESSES
SPECIAL MACHINERY FOR STEEL MILLS

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DESIGNERS
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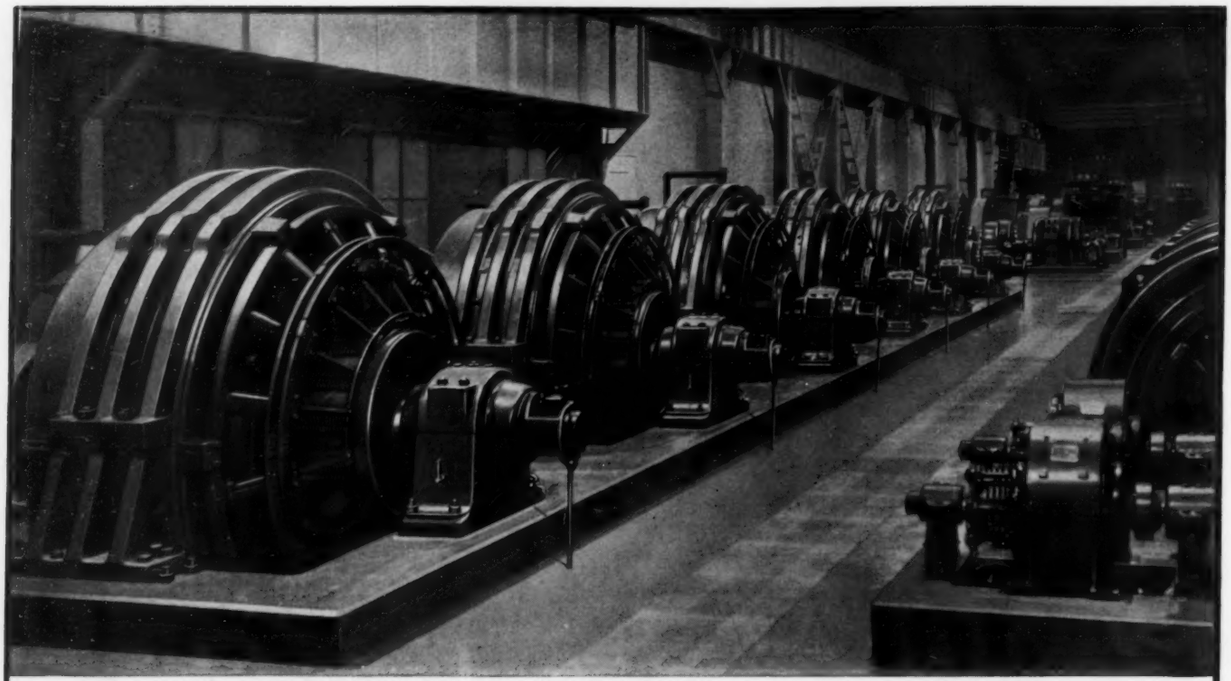
THE MORGAN ENGINEERING COMPANY

New York, 25 Broadway **ALLIANCE, OHIO** *Pittsburgh, 1420 Oliver Bldg.*

A. I. & S. E. E. — TWENTY-FIVE YEARS OF ENGINEERING SERVICE TO THE IRON & STEEL INDUSTRY

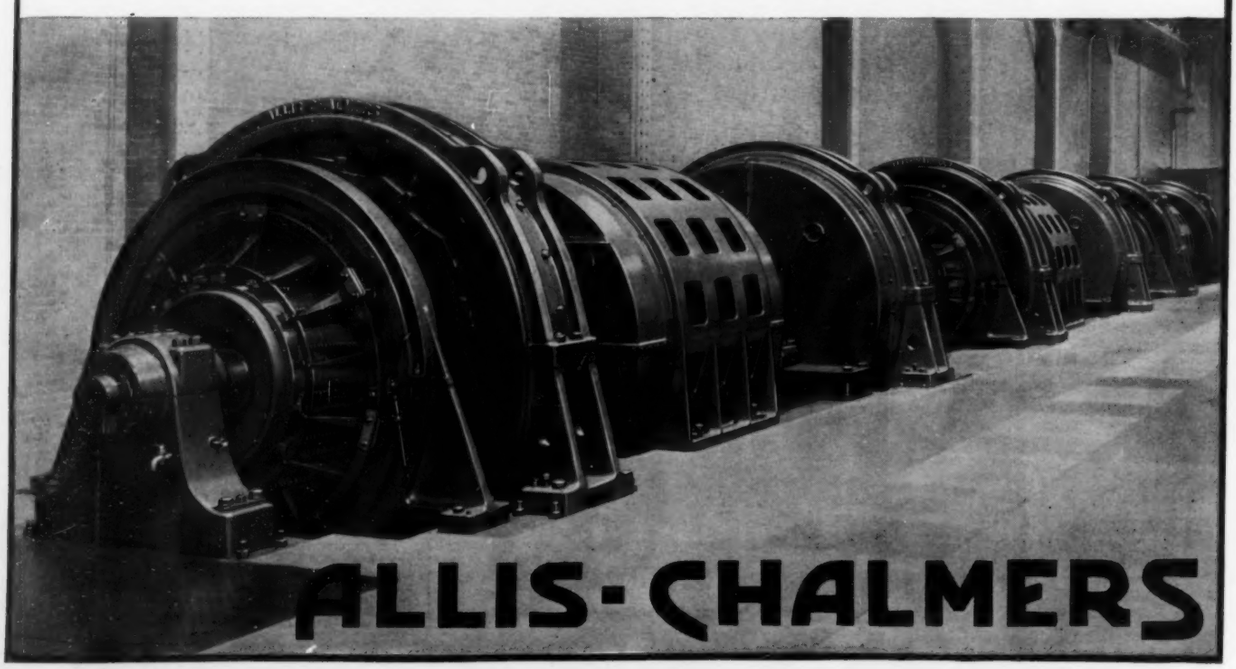


21,500 H.P., BACKED BY 15,000 K.W.,

DRIVING 76" CONTINUOUS HOT STRIP FINISHING MILL . . . . . .

This powerful d.c. drive in the "hot mill" of the Inland Steel Company, Indiana Harbor, was furnished complete with control, switchgear, and transformers by Allis-Chalmers Mfg. Co. Six 3500 hp., 175/350 r.p.m., 600 volt, d.c. motors drive six finishing stands. These motors, together with a 500 hp. scale breaker motor, are powered from three 5000 kw., 500 r.p.m., 6600 volt, three phase, 25-cycle, unity power factor, three-machine synchronous motor-generator sets. The "Frog Leg" windings on the direct current machines give 100% cross connection *without cross connectors or additional soldered joints.*

Allis-Chalmers Mfg. Company, Milwaukee, Wis.



UNFAILING SKF'S AND PILLOW BLOCKS FOR PERFORMANCE

WHERE PERFORMANCE TAKES PREFERENCE OVER PRICE

HANDICAP? To be out in the open under all sorts of weather conditions? Not for the SKF Ball Bearings and Pillow Blocks on this Fairbanks-Morse deep well pumping plant. Long-life, dependability and a minimum of maintenance are demanded here and SKF's live up to such rigid requirements. Obviously, SKF Performance Takes Preference Over Price.

In numerous industries, SKF Bearings and Pillow Blocks are used on a wide variety of light and heavy duty equipment because unfailing performance is assured. SKF Bearings run smoothly, require less power, show no wear and need no adjustments. SKF Pillow Blocks are rugged and give protection to the bearings against dirt, dust and moisture. SKF Bearings and Pillow Blocks are made to fit shaft sizes from 5/8 to 14¾ inches in diameter. Specify them for trouble-free, low cost operation on new equipment or for replacements.

● *You may buy a bearing as a bargain but try and get a bargain out of using it, for nothing is apt to cost so much as a bearing that cost so little.*

2940

SKF INDUSTRIES, INC. 40 EAST 34th STREET, NEW YORK, N. Y.

SKF

Ball and Roller Bearings

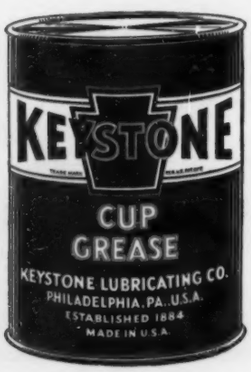
Feed this KEYSTONE diet through your GREASE CUPS

LUBRICATION engineers agree that there is a proper lubricating diet required for various mechanical conditions. This Keystone diet is recommended after a careful study of conditions in various fields, plus the knowledge acquired in 48 years of lubricating experience.

HARD Cup Grease was especially formulated for engine and general machinery use—for high speed crank pins, cross heads, eccentric straps, main and outboard bearings, and on all bearings where the use of heavy or solid grease is required. Used in hand compression cups and in spring compression cups of the Organ Type "A" style.

MEDIUM Cup Grease was especially formulated for high speed electrical and woodworking machinery; also on ball and roller bearings and governors of high and low speed. Highly recommended for gear cases of pneumatic tools and for bevel gear housings of multiple spindle-boring machines. Used in hand compression cups and spring compression cups.

SOFT Cup Grease was especially formulated for line shafting lubrication and is suitable for use in most plain bearings in "Venango" Gravity Grease Cups.



Keystone Cup Grease is also available in extra soft and extra hard densities

KEYSTONE LUBRICATING COMPANY
21st, Clearfield and Lippincott Sts., Philadelphia. Est. 1884

KEYSTONE LUBRICANTS

Your Keystone Distributor will be glad to supply you with further information, or a trial order of Keystone Cup Grease.

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Calif.,	*Los Angeles,* The Keystone Lubricating Co.
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	Passaic, H. W. Mills & Co., Inc.
	Paterson, H. W. Mills & Co., Inc.
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	New York City, A. P. Dienst Co., Inc.
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KEYSTONE TRADE MARK REG. U.S. PAT. OFF.
GREASE

Ready for Instant service!

Pennsylvania Heavy-Duty Transformers are shipped completely assembled and filled with oil, ready for service.

Radiators are permanently welded to tank. Individual radiator tubes can be easily cleaned and painted. Cost of installation as well as maintenance is thereby greatly reduced.

This company is meeting the needs of the largest industrials and utilities with a complete line of distribution and power transformers.

PENNSYLVANIA TRANSFORMER CO.

28th St. & A. V. R. R. - Pittsburgh, Pa.

Representatives in Principal Cities

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PENNSYLVANIA TRANSFORMERS

DISTRIBUTION AND POWER

KACHCHHA

The yogis of the Hindu maintain that they can project their minds to any portion of the world they wish to visit, while their bodies remain at home on useful work—kachchha, they call it.

Projecting the mind in this manner is no trick at all, as most of us can attest, but to keep the body usefully employed at the same time is a feat—with little call for it.

Much more can be accomplished by keeping mental and physical effort in the same channel.

In other words, if your mind is now yearning for better commutation or for lower annual brush cost—it will net you very little until you physically grab a pen or phone and through it get in touch with one of the addresses below.

Morganite Brush Co., Inc.

Main Office and Factory
3302-3320 Anable Ave., Long Island City, N. Y.

DISTRICT ENGINEERS AND AGENTS

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Birmingham, Ala., A. J. Bowron, 435 Brown-Marx Building.
Revere, Mass., J. F. Drummey, 62 Pleasant Street
Los Angeles, Electrical Engineering Sales Co., 575 Subway Terminal Building.
San Francisco, Electrical Engineering Sales Co., 622 Underwood Bldg.
Toledo, Ohio, T. U. Franklin, 1360 Rollins Road
Chicago, Ill., E. E. Smith, 806 Grace Street
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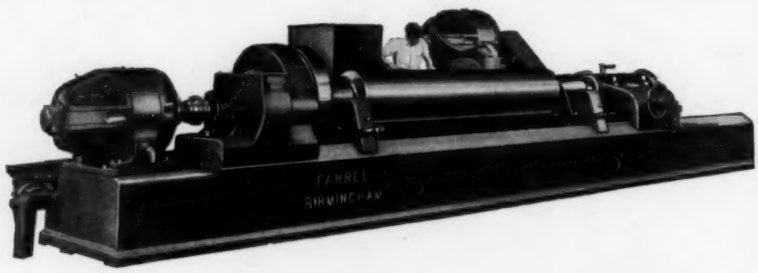
Montreal, Can., Railway & Power Engineering Corp., Ltd., 3745 St. James Street West
Winnipeg, Can., Railway & Power Engineering Corp., Ltd., P. O. 325



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Former roll conditioning methods which required dependence upon the variable element of human attention and judgment are obsolete. Slow, costly methods and variable results need no longer be a necessary evil in your plant.

The Farrel Heavy Duty Roll Grinder brings the accuracy and finish of rolls under close control and enables the plant management to fix definite standards of precision and quality of finish, and to maintain such standards.

In addition to substantial savings in roll finishing costs and in longer roll life, the control of roll accuracy and finish permits control of the quality of steel sheets, assures uniformity of gauge and diminishes the quantity of sub-standard product. Farrel engineers are prepared to make a survey to determine the savings possible under your individual conditions. Consultation involves no obligation.

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Even in times like these Baker Trucks are amortizing their cost *and in addition* paying big dividends. These are *provable* facts. Don't *assume* that your costs are as low as possible. Let a Baker engineer survey your handling methods, and give you a report of facts and figures. You have everything to gain and nothing to lose. Isn't it just good business to find out?

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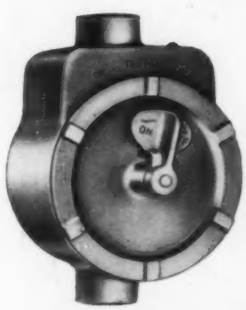

Type FLDC
Appliance Breaker Condulet

Listed and described in Bulletin 2254, which will be sent on request.

Type FLC
Circuit Breaker Condulet

Type FLFC
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ESTABLISHED 1897
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In All Voltages

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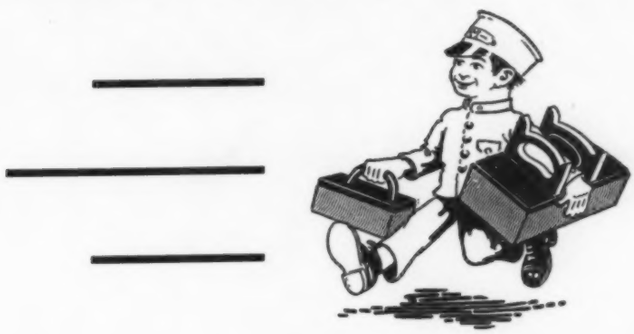

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Up to 430 tons capacity

STRIPPING CRANES
Up to 320 tons capacity

COMBINATION CHARGERS and STRIPPERS
Up to 200 tons capacity

- Ladle Cranes
- Ingot Strippers
- Soaking Pit Cranes
- Open Hearth Charging Machines
- Slab and Billet Charging and Drawing Machines
- Gantry Cranes
- Ore and Coal Bridges
- Car Dumpers
- Forging Manipulators
- Steam Drop Forge Hammers
- Coke Pushers, Levelers and Door Lifters
- Coal Pier Equipment
- Rolling Mill Machinery
- Cement Plant Machinery
- Dock Handling Equipment
- Coke Oven Equipment

275 of 100 Tons Capacity and over

LADLE AND STANDARD CRANES

59		100 tons
2	WORM DRIVEN Ladle,	100 tons
2		115 tons
6	WORM DRIVEN Ladle,	125 tons
45		125 tons
30		150 tons
3	WORM DRIVEN Ladle,	150 tons
6	WORM DRIVEN Ladle,	160 tons
2	WORM DRIVEN Ladle,	165 tons
7	WORM DRIVEN Ladle,	175 tons
27		175 tons
3	WORM DRIVEN Ladle,	200 tons
4		200 tons
5		225 tons
1		250 tons
3	WORM DRIVEN Ladle,	250 tons
3	WORM DRIVEN Ladle,	275 tons
1		275 tons
1		300 tons
3		430 tons

STRIPPING CRANES

8		100 tons
1		125 tons
22		150 tons
19		200 tons
1	Single Ram,	320 tons

COMBINATION CHARGERS AND STRIPPERS

3		100 tons
1		125 tons
3		150 tons
4		200 tons

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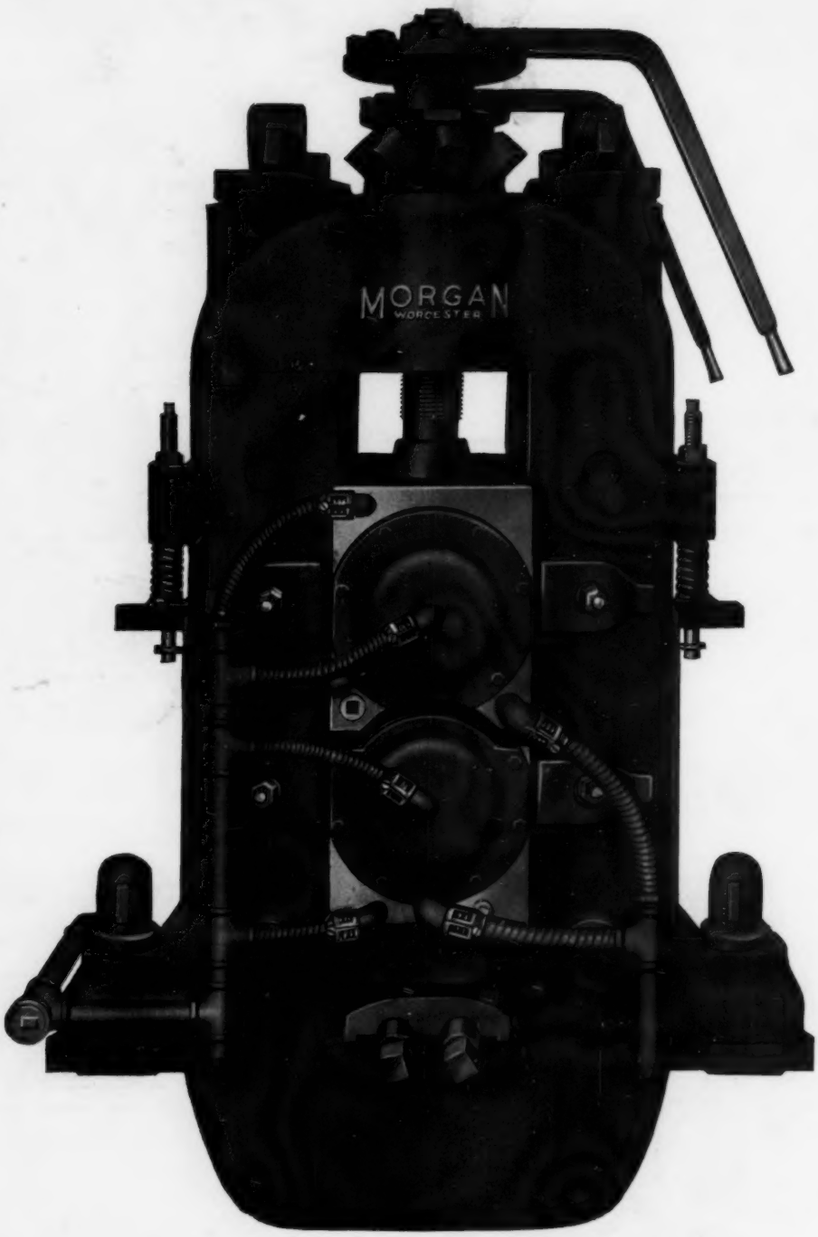

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